Am. B.

3040

(418)

8°

Proceedings

THE

MISCELLANEOUS DOCUMENTS

OF THE

SENATE OF THE UNITED STATES

FOR THE

SECOND SESSION OF THE FIFTY-FIRST CONGRESS.

1890-'91.

VOLUME 6.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1894.

BIBLIOTHECA
REGIA
MONACENSIS

51ST CONGRESS, 2d Session. } SENATE. { MIS. DOC. No. 94.

MEMOIRS

OF THE

NATIONAL ACADEMY OF SCIENCES.

Volume V.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1891.

TABLE OF CONTENTS.

Page.

ENERGY AND VISION, by S. P. Langley 7–18

CONTRIBUTIONS TO METEOROLOGY, by Elias Loomis 21–109

REPORT OF STUDIES OF ATMOSPHERIC ELECTRICITY, by T. C. Mendenhall 113–318

THE EMBRYOLOGY AND METAMORPHOSIS OF THE MACROURA, by W. K. Brooks and F. H. Herrick 321–576

ON THE APPLICATION OF INTERFERENCE METHODS TO ASTRONOMICAL MEASUREMENTS, by A. A. Michelson 579–590

NATIONAL ACADEMY OF SCIENCES.

VOL. V.

FIRST MEMOIR.

ENERGY AND VISION.

ENERGY AND VISION.

By S. P. LANGLEY.

[Read by abstract, April 19, 1888.]

While it is quite a familiar fact that the luminosity of any spectral ray increases proportionately to the heat in this ray, and indeed is but another manifestation of the same energy, I have recently had occasion to notice that there is on the part of some physicists a failure to recognize how totally different optical effects may be produced by one and the same amount of energy according to the wave length in which this energy is exhibited.

I should not, perhaps, have thought it advisable to make this last remark were it not that there has appeared in a recent number of Wiedemann's Annalen a paper by H. F. Weber on "The Emission of Light," in which he tacitly makes the assumption that the luminosity of a color is proportionate to the energy which produces it, an assumption which it is surprising to find in a paper of such general merit and interest.

In another article of the same number of the journal the mistake was pointed out by Prof. F. Stenger, who remarked that Mr. Weber's assumption is inconsistent with the investigations of the present writer. Still the fact that there could be such a misapprehension at the present day led me to look at the matter again, and to observe, with some surprise, that there was nowhere in any physical work known to me any exact or even approximately exact statement of the relative ocular effects of a given amount of energy in different parts of the spectrum.

I have undertaken, therefore, during the last few months, an experimental re-investigation of this subject, with such a statement especially in view.

We shall evidently need two correlated sets of experiments; the first set to determine the amount of energy in each ray, the second to show the corresponding visual effect.

For the first of these, since energy shows itself only through absorptive media which more or less disguise it, we must select that manifestation which disguises it least, and in this respect beyond comparison the thermal one stands first, as the *heat* dispersed by a glass prism and shown by a lampblacked thermometric apparatus is, throughout the visible spectrum, very nearly proportionate to the energy itself. For these first or thermal experiments, from which the energy is readily deduced with close approximation, we shall rely principally upon a very elaborate investigation made here some time since and already published, where the bolometer is used to deduce in terms of lampblack absorption the relative amounts of solar energy in various wave lengths throughout the visible spectrum and a little beyond, and which has been supplemented by a new investigation of the same kind in the present connection.

Our second set of experiments will consist of a recent parallel series of photometric solar measures taken at the same wave lengths as the thermal ones, and which we may say gives this energy in terms of what I may perhaps be allowed to call, provisionally, "retinal" absorption.

The lampblacked surface, then, and the retinal screen provided by nature in the eye, both exercise selective absorption; but the first does so in relatively so small a degree, that we may, in the visible spectrum, provisionally neglect it, and consider the bolometric effect as here proportional to the energy itself.

It is evident that these two series once made, and reduced in both cases to the normal spectrum, would give us for any individual human eye the means of stating the visual effect in

terms of absolute energy. The visual effect is known to vary in a very minute degree with the absolute amount of this energy, at least if we admit the physiological influence of what has been called "the color of brightness," but for the comparatively feeble lights employed, this physiological effect seems to be almost negligible, and it is nearly immaterial within the limits of the experiment what unit of energy we take.

The object of these experiments, then, is to take some one constant amount of energy, to actually or virtually display it successively in different portions of the spectrum, and to observe in what proportion the optical or visual effects of this fixed amount of energy vary, according to the wave-length in which it is conveyed. While the measurements which insure this constancy are best made by thermal methods, and while the prism is on the whole far more convenient for them than the grating, it is nevertheless desirable to reduce the whole measurements to what they would have been if taken directly in the normal spectrum.

The writer's measurements, already published and here cited later, afford the means of doing this with precision. These show that the energy is far from being distributed equally even in the normal spectrum, and in fact, according as it varies from one part of the spectrum to another, we must, by opening the aperture through which it is admitted where it is weak, and by narrowing it where the energy is strong, or by other like device, maintain it absolutely constant, or else (what is far better) let it enter through one fixed aperture, and use the subjoined table to apply a correction for the actual irregularities. Let it be remembered that we are now speaking of absolute energy, not of those physiological effects of it on the organ of vision which we call light, and it is to the value of this absolute energy for different wave-lengths in the normal spectrum that the subjoined table refers. This table, which gives the energy as derived from thermal experiments, rests on many thousand observations, taken, however, all with what is called a high sun, *i. e.*, with a sun more than 30° above the horizon. As the distribution of this energy varies somewhat from day to day, and particularly in the violet and beyond, we have supplemented it by a series of direct observations taken with the bolometer on April 6, 1888, using the same glass prism employed in the photometric work described later. As these observations show a fair accordance with the others, it is not necessary to repeat them.

TABLE I.

λ =	$0^{\mu}.34$	$0^{\mu}.38$	$0^{\mu}.40$	$0^{\mu}.45$	$0^{\mu}.50$	$0^{\mu}.55$	$0^{\mu}.60$	$0^{\mu}.65$	$0^{\mu}.70$	$0^{\mu}.75$	$0^{\mu}.77$
Heat =	1.8	3.7	5.3	11.9	17.3	20.7	21.9	22.2	21.4	20.7	20.2

It is well known that color-photometry offers peculiar difficulties. The writer's own experience, after a long employment of the Rumford photometer for comparing the relative intensity of different-colored lights, is most unfavorable to it, and he also tried the Bunsen photometer with almost equally unsatisfactory results. He has also experimented with the ingenious photometer described by Masson (Ann. de chim. et de phys., Par. ser. III, t. XIV, p. 129), in which a disk of paper, marked with black and white sectors, is revolved with such rapidity that it assumes a uniform tint when viewed by the colored light in question, but which, when illuminated by the electric flash, displays the sectors again. It is evident that the reappearance of the sectors under the flash will be conditioned by the nature of the light which furnishes the steady illumination. But though on trial this has seemed to yield better results than the ordinary photometers, the method is of difficult application in connection with the particular apparatus about to be described. I have, therefore, after considerable experiment, decided in favor of what may seem, at first, to be a cruder method, but which is, I believe, for the present purpose, preferable to any of the foregoing; I mean the determination of the intensity of light necessary to read a table of logarithms, or to discern any arbitrary characters.

DESCRIPTION OF THE APPARATUS.

The measures have all been made in a dark room, from which every source of outside light is excluded, except that which enters the slit of the spectroscope.

The light from the siderostat mirror M (Plate I) passes through a small aperture in the north wall and falls on the slit (s_1) (which has doubly-moving jaws, 34^{mm} high, set in these experiments at a standard distance of $0^{mm}.1$), then on the great collimating lens (l) of 755^{cm} focus (aperture $11^{cm}.9$), t_1 being a paper tube to prevent the lateral diffusion of light from dust particles. p is a glass prism* m, the concave mirror of 148^{cm} focus, which here forms upon a second slit (s_2) a spectrum about 7^{mm} high and 90^{mm} long in the easily visible part from A to H. The prism and mirror are mounted on the spectro-bolometer, already elsewhere described,† which is provided with a circle reading to 10″ of arc. By setting this circle, any color can be brought on this slit (s_2). The light which the mirror has converged into that part of the spectrum overlying the slit passes through it, diverges, and falls upon a black paper, Plate I, fig. 1, in which is a central aperture 1^{cm} square, occupied by part of a table of logarithms, printed in small black type on white paper. This table can be adjusted to bring different figures in view, but is otherwise fixed relatively to the black paper screen which (with this central centimetre occupied by figures) is mounted on a slider. The rod (r) on which the slider moves is a prolongation of the spectroscope arm, made of a light wooden rod graduated so that one can read the position of the slider to a centimetre by *feeling* of notches in the dark. The zero of this rod is at slit 2, on which the spectrum is thrown.

It is to be observed that it is necessary that the square of figures should be small in order that it may be slid nearly to the apex of the cone of light and remain covered thereby.

It is to be noted also that at a constant distance and in a feeble light, these small figures may be invisible to the naked eye and most distinctly visible to the same eye with a magnifying glass. For two eyes of different foci, the distance, then, at which the same figures will be read in the same light will probably vary. It follows that even if the same person read from beginning to end of the series, his readings will not be comparable unless they are all taken under the same optical conditions, *e. g.*, all with the naked eye or all with glasses of a certain strength.

In these measurements a magnifying glass of $4^{cm}.7$ focus was used by all the observers and in addition, two who were nearsighted wore spectacles correcting this defect.

The observer, in a room completely darkened except for the minute light diffused from the particles in the reflected beam, and himself shielded even from the feeble light diffused from the surfaces of the lens, the prism, and the mirror, by the thick black curtain shown on the plan, waited until his eye had become quite sensitive before making the readings. An assistant outside the curtain set the circle by the aid of a dark lantern, and adjusted the siderostat from time to time so as to keep the light exactly on the center of the lens and prism face. The passage of the slightest wisp of cirrus cloud was noted and the observer warned.

Although the light diverges from slit 2 and not from a point, the "cone of rays" above referred to, is, as regards the object and limits of our experiments and the limiting positions of the screen, so nearly coincident with a geometrical cone, that, as the slider is carried away from the slit, the light may be treated as diminishing proportionally to the inverse square of the distance from the slit to the screen. The nearest position of the screen brings it within 20^{cm} of the slit, the furthest is over 300, so that we have the power of diminishing the light over $(\frac{300}{20})^2$ or over 225 times. Even this, however, is by no means a sufficient range for the comparison of the light in the yellow green with that in the extreme red; and because the graduated rod was not long enough to thus give the desired range, a photometer wheel was introduced in some of the measures between the siderostat mirror and the remote slit (s_1). This photometer wheel is capable of reducing the light from .50 to .05 or further, and is more fully described in Memoirs National Academy of Sciences, vol. 3, Memoir on the Temperature of the Moon. We have, then, without

---

* Its principal constants are: height of face, $11^{cm}.5$; width, $10^{cm}.5$; while for a temperature of 28° C. the refracting angle is 60° 06′ 45″; deviation,

	°	′	″
H	46	45	35
b_1	44	45	55
D_2	44	11	15
A	43	24	05
ω_2	41	34	00

† "Researches on Solar Heat," Prof. Papers of the Sig. Serv. No. 15, p. 130.

altering the slit, a range of adjustment through over $\frac{225}{.05}$ or over 4,500 times. The slit s_1 where the light first enters, has doubly-moving jaws controlled by a micrometer screw. Its standard opening in these experiments for light comprised between $\lambda=0^{\mu}.40$ (violet) and $\lambda=0^{\mu}.65$ (red) was $0^{mm}.1$, but it has been opened for supplementary experiments to 5^{mm}, so that we have by opening or closing it a range of light from 50 to 1. It was, however, constantly kept at the standard opening of $0^{mm}.1$ until the main series of experiments was completed so as not to vary the light by attempting to reset it by the screw. Admitting, however, that for any given prism, transmitting any given ray, the light is sensibly proportional to the width of the slit (which may vary from 50 to 1), to the disposition of that coming through the photometer wheel, which may vary from 20 to 1, and to the inverse square of the distance of the slider from slit s_2 (225 to 1), we have a possible range of $50\times20\times225=225{,}000$ to 1. This, however, it will be understood has only been employed in our supplementary measures.

In the following table all observations, whether made with or without the photometer wheel or with a wide slit, as in the case of the supplementary observations in the most feebly luminous portions at the extremities of the spectrum, have been reduced to these standard conditions:

Photometer wheel absent;
Slit (s_1) $0^{mm}.1$ wide;
Slit (s_2) 1^{mm} wide;
Slider with logarithm table at 1 metre from slit s_2.

Each reading of the logarithms in slider is taken when certain figures become discernible in the light in question, and is the mean of three independent observations, taken consecutively. In order to find the wave-length by means of the prism, we must prepare a table or a graphic construction, deduced from an examination of the special prism employed, showing the wave-length corresponding to the position of minimum deviation of each ray. Fig. 2, plate II, is such a graphic construction, derived from our own observations of the constants of the prism employed, and Table II gives the approximate value of the tangents to the curve by means of which we pass from the prismatic to the normal scale.

TABLE II.—*Approximate deviations and reducing factors (tangents) corresponding to adopted wave-lengths for great Hilger prism.*

Wave-lengths.	Adopted tangents to curve.	Deviations.
μ		° ′
.35	2.28	48 00
.38	1.94	47 10
.40	1.73	46 42
.45	1.27	45 42
.50	.88	44 58
.55	.62	44 28
.60	.46	44 07
.65	.36	43 50
.70	.30	43 38
.75	.27	43 26
.77	.26	43 22

TABLE III.—*Coefficients of reflections from two surfaces of silver.*

Wave-lengths	.35	.38	.40	.45	.50	.55	.60	.65	.70	.75
Reflection, two surfaces	.37	.54	.63	.73	.79	.82	.845	.86	.875	.885
Reduction factor	2.70	1.85	1.59	1.37	1.27	1.22	1.18	1.16	1.14	1.13

Table III is a table for the selective absorption of silver referred to such a lamina as is spread by the Martin process on the front surface of the glass in its ordinary application. It is prepared from unpublished observations made by the writer with the bolometer in the course of

the year 1881; and for the method of its preparation the reader is referred to the foot-note.* It will be seen from this table that while such a silver film exercises a considerable selective absorption in the ultra-violet and even at the blue end, it is an almost perfect reflector for infra red rays. It is with these that our measures in previous researches on radiant heat at this observatory have been mainly made. Accordingly our measures of the selective reflection in the ultra-violet, to which we have given comparatively little study, have not been repeated with all the care the subject deserves, and we recommend a more complete determination of the selective absorbtion of silver there as an interesting field still open for experiment to those engaged in the study of that end of the spectrum.

By means of this graphic construction, which is amply accurate for the immediate purpose, and by the use of the formula already described in Memoirs of the National Academy, vol. II, p. 161, we can also pass from the actually observed prismatic spectrum to the effect which would have been observed in a truly normal one; and it is by the use of these constructions, founded on these formulæ, that the final reductions here given have been obtained. I should add that it is here momentarily assumed that no selective absorption is exerted by the prism or any other portion of the apparatus. The corrections for the actual selective absorption in the substance of the prism or the carbon on the bolometer strip will be given later.

We now give a summary of the photometric observations.

The state of sky for each series and the approximate air masses were:

March 30.—Sky "fair blue;" observer, S. P. L.; time, $11^h\ 40^m$ a. m. to $12^h\ 45^m$ p. m. (Greenwich, fifth-hour meridian time); air mass, 1.22 atmospheres.

April 2.—Sky "milky blue, with cumuli;" observer, F. W. V.; time, 12^h to 2^h p. m.; air mass, 1.19 atmospheres.

April 3.—Sky "blue, with cumuli," better than on 2d. Sky better in E. M.'s series than in that of F. W. V., when a slight haze, barely perceptible, had formed.

First series: Observer, E. M.; time, $11^h\ 10^m$ a. m. to $12^h\ 30^m$ p. m.; air mass, 1.18 atmospheres.

Second series: Observer, F. W. V.; time, $1^h\ 15^m$ to $2^h\ 30^m$ p. m.; air mass, 1.28 atmospheres.

April 4.—"A good blue at first, after 12^h milky blue from slight smoke, but still a fairly good sky."

First series: Observer, F. W. V.; time, $10^h\ 25^m$ to $11^h\ 55^m$ p. m.; air mass, 1.23 atmospheres.

Second series: observer, E. M.; time $12^h\ 30^m$ to $1^h\ 30^m$ p. m.; air mass, 1.20 atmospheres.

April 6.—Sky "good blue, quite clear;" observer, F. W. V.; time, $10^h\ 45^m$ a. m. to $12^h\ 15^m$ p. m.; air mass, 1.18 atmospheres.

June 16.—Sky "clear, good blue;" after 1 p. m. cirrus streaks; observer, B. E. L.; time, $11^h\ 15^m$ a. m. to $1^h\ 45^m$ p. m.; air mass, 1.05 atmospheres.

July 2.—Sky "clear, excellent;" observer, B. E. L.

First series: Time, $11^h\ 25^m$ a. m. to $12^h\ 15^m$ p. m.; air mass, 1.03 atmospheres.

Second series; Time, $12^h\ 15^m$ p. m. to $1^h\ 25^m$ p. m.; air mass, 1.02 atmospheres.

We first give, in Table IV, the values of the photometric measures in the prismatic spectrum reduced to the standard conditions above cited.

---

* The selective absorption of silver has been deduced by bolometric measurements in the solar spectrum with a Rutherfurd grating by producing multiplied successive reflections of the light from silver before allowing it to enter the slit of the spectroscope, and in determining successively the variation in the intensity of different rays according to the number of reflections. The observations are reduced by a logarithmic formula.

TABLE IV.—*Showing sensitiveness of the eye to light, as deduced from the power to decipher fine print.*

[Prismatic (uncorrected) values.]

λ =	$0^{\mu}.35$	$0^{\mu}.38$	$0^{\mu}.40$	$0^{\mu}.45$	$0^{\mu}.50$	$0^{\mu}.55$	$0^{\mu}.60$	$0^{\mu}.65$	$0^{\mu}.70$	$0^{\mu}.75$	$0^{\mu}.77$
S. P. L.:											
March 30	.....	.....	.....	0.29	3.01	19.31	19.15	3.88	0.28	.....	.....
F. W. V.:											
April 2	.....	.....	0.13	9.89	57.9	113.3	15.14	1.06	0.27	.....	.....
April 3	.....	.....	0.30	9.88	154.2	167.9	26.91	1.99	0.43	.....	.....
April 4	.....	.....	0.20	10.88	154.6	193.8	24.62	2.23	0.33	.....	.....
April 6	*0.0015	*0.017	*0.17	.....	.....	.....	.....	2.32	.....	*0.005	*0.0012
Mean	0.0015	0.017	0.20	10.25	122.25	158.33	22.22	1.90	0.34	0.005	0.0012
B. E. L.:											
June 16	.....	.....	0.24	30.60	157.2	217.0	36.98	3.39	0.17	*0.001	.....
July 2	0.000	*0.003	0.23	10.89	125.7	142.3	33.96	4.54	0.73	*0.004	.....
July 2	.....	.....	0.34	35.38	186.1	158.7	70.16	5.98	0.75	.....	.....
Mean	.....	0.003	0.27	25.62	156.3	172.7	47.03	4.64	0.55	0.002	.....
E. M.:											
April 3	.....	.....	0.35	30.60	100.1	146.1	40.82	5.85	1.46	.....	.....
April 4	.....	.....	0.19	8.34	46.4	75.3	42.05	3.04	.....	.....	.....
Mean	.....	.....	0.27	19.47	73.25	110.70	45.94	4.45	1.46	.....	.....

* Blue (cobalt) glass over slit s_1.

In Table V are the final values, corrected for loss of light by reflection from silver surfaces and reduced to the normal spectrum.

TABLE V.—*Photometric values.—Normal spectrum.*

λ=	$0^{\mu}.35$	$0^{\mu}.38$	$0^{\mu}.40$	$0^{\mu}.45$	$0^{\mu}.50$	$0^{\mu}.55$	$0^{\mu}.60$	$0^{\mu}.65$	$0^{\mu}.70$	$0^{\mu}.75$	$0^{\mu}.77$
S. P. L.:											
March 30	.....	.....	.....	0.50	3.36	14.61	10.40	1.62	0.096	.....	.....
F. W. V.:											
April 2	.....	.....	0.36	17.31	64.76	85.7	8.22	0.44	0.09	.....	.....
April 3	.....	.....	0.81	17.18	172.4	127.0	14.61	0.83	0.15	.....	.....
April 4	.....	.....	0.56	19.11	172.8	146.7	13.37	0.93	0.11	.....	.....
April 6	*0.0092	*0.062	*0.47	.....	.....	.....	.....	0.97	.....	*0.0015	*0.0003
Mean	0.0092	0.062	0.55	17.83	136.65	119.8	12.07	0.79	0.12	0.0015	0.0003
B. E. L.:											
June 16	.....	.....	0.66	53.23	175.7	164.2	20.07	1.42	0.06	*.0003	.....
July 2	*0.000	*0.011	0.63	18.95	140.5	107.6	18.44	1.90	0.25	*.0012	.....
July 2	.....	.....	0.94	61.56	208.0	120.0	38.09	2.50	0.26	.....	.....
Mean	0.000	0.011	0.74	44.58	174.7	130.6	25.53	1.97	0.19	.0008	.....
E. M.:											
April 3	.....	.....	0.95	53.23	111.90	110.5	27.05	2.44	0.50	.....	.....
April 4	.....	.....	0.52	14.51	51.84	56.9	22.82	1.27	.....	.....	.....
Mean	.....	.....	0.74	33.87	81.87	83.7	24.94	1.86	0.50	.....	.....

*Blue (cobalt) glass over slit (s_1).

In this table we have, first, the wave-lengths corresponding to the observed angles of deviation, these angles reaching from $0^{\mu}.35$ in the ultra.violet to $0^{\mu}.77$ near Fraunhofer's A on the extreme border of the visible red. It is to be observed, however, that the great mass of the observations which were taken without disturbing the slit reach from $0^{\mu}.40$ in the deep violet to $0^{\mu}.70$ in the

deep red. The figures corresponding to $0^{\mu}.35$, $0^{\mu}.38$, $0^{\mu}.75$, $0^{\mu}.77$ are extremely difficult to obtain with precision and are given here as supplementary to the others. There are four observers:

S. P. L., whose eye is somewhat long-sighted, making convenient the use of convex glasses of $\frac{1}{2}$ metre focus; and not sensitive to very feeble light; eyes otherwise believed to be in normal condition.

F. W. V., near-sighted, using glasses whose negative focus is 14 centimetres. The eye appears to be much less sensitive to the red than to the violet. The retina of this eye is somewhat deficient in black pigment.

B. E. L., near-sighted, using glasses whose negative focus is 42 centimetres.

E. M., a boy of 15 whose sight is perfect as far as known.

It will be remembered that throughout this table from $0^{\mu}.40$ to $0^{\mu}.70$ the light enters through a slit whose aperture is constant. If under these conditions the logarithm table can be just read when the slider is 1 metre from the second slit (s_2), the light would be represented by unity; if at 2 metres, by 4; if at 3 metres, by 9; and so on. As, however, we have already explained, the length of the rod being limited to but little over 3 metres, for the higher values we are obliged to introduce the photometer wheel. For instance, the strongest light observed by F. W. V. was in the prismatic yellow-green corresponding to a wave-length of $0^{\mu}.55$, where 193.8 was noted. Had the red been really indefinitely prolongable, the slider would have needed to have been removed to the length of nearly 14 metres. To avoid this the photometer wheel was interposed, reducing the light to $\frac{1}{20}$, and the actual distance of the slider from the slit (s_2) was, as we may easily see, $\sqrt{\frac{193.8}{20}}$ or 3.11 metres. The feeblest light which has been here measured with the standard slit is that by F. W. V. on April 2 at wave-length $0^{\mu}.40$, which is put down at .13, corresponding to a distance of 36 centimetres from slit (s_2).

To make clear the way in which we pass from Table IV to Table V, let us take any particular observation, for instance that already cited of April 4, by F. W. V., at $0^{\mu}.55$ of 193.8. Referring either to the graphic construction or to Table I, we find the value of the tangent at ($\lambda = 0^{\mu}.55$) = 0.62, approximately, and $193.8 \times .62 = 120.16$. Our table shows the reduction factor for two surfaces of silver to be 1.22, whence the final reduced value becomes

$$1.22 \times 120.16 = 146.6.$$

And in this manner from Tables II and III the remaining values in Table V are derived from those in IV; but here let it be observed that these values in Table V do not yet represent what we wish, since they do not correspond in any exact sense to one constant amount of energy. It is true that they might at first sight appear to do so, since one constant quantity of solar energy actually or virtually entered through the same constant width of the slit to produce them, and passed through one constant aperture at the second slit, and since finally the prismatic values are reduced to those in the normal spectrum; but, as the writer has shown, not only by theoretical deductions from what is observed with the prism, but by very numerous measures in the normal spectrum from a grating by means of a bolometer, the solar energy in the normal spectrum itself is very unequally distributed. (See Table I.)

Since thermal and luminous effects vary proportionately in the same ray, it is to be observed that the values in Table I furnish for each wave-length a divisor which gives not only the heat but the *brightness* which would have been observed had the prism dispersed the energy which fell on it in such a way that the same amount of energy fell in one part of the spectrum as in another, and thus we finally obtain the values in Table VI.

TABLE VI.—*Sensitiveness of the eye for a constant amount of energy of varying wave-length.*

$\lambda =$	$0^{\mu}.35$	$0^{\mu}.38$	$0^{\mu}.40$	$0^{\mu}.45$	$0^{\mu}.50$	$0^{\mu}.55$	$0^{\mu}.60$	$0^{\mu}.65$	$0^{\mu}.70$	$0^{\mu}.75$	$0^{\mu}.768$
S. P. L	.....	.....	.....	0.042	0.194	0.706	0.475	0.073	0.004	.....	.....
F. W. V	0.0051	0.0168	0.104	1.50	7.90	5.79	0.551	0.036	0.005	0.00007	0.00001
B. E. L	.....	0.0030	0,139	3.75	10.10	6.31	1.17	0.089	0.009	0.00004	.....
E. M	.....	.....	0.140	2.85	4.73	4.04	1.14	0.084	0 023	.....	.....

It will be observed that no correction has been introduced for selective absorption in the substance of the prism itself, as this is absolutely negligible within the limited range of the spectrum we are discussing.

The last four lines of the table exhibit the relative effect upon different eyes of a given amount of energy in the form of radiation of various wave-lengths.

Quite notable differences exist between the different observers, not only as to the absolute sensitiveness of the eye, but also as to the relative efficiency for different colors. This seems to be, to some extent, a function of the age of the observer, if we may draw any conclusion from so few comparisons, the younger eyes being much more sensitive to the rays of shorter wave-length. Beyond this, any unusual efficiency for a particular part of the spectrum is perhaps apt to be balanced by a deficiency in another part, which, if strongly pronounced, would be termed color blindness.

Prof. J. Clerk Maxwell, employing pure spectrum colors, formed white by combining 26.3 per cent. of red with 30.2 per cent. of green and 43.5 per cent. of blue (Phil. Trans. R. Soc., 1860, p. 79), and on another occasion with a slightly different apparatus (*loc. cit.*, p. 74) the same observer made white by mingling 21.9 per cent. of red with 33.3 per cent. of green and 44.8 per cent. of blue. The Allegheny observers, F. W. V., B. E. L., and E. M., with whom this experiment was repeated, required from one-fourth to one-tenth less red and one-sixth to one-eighth more blue than Maxwell, forming white by mingling 20 per cent. of red with 30 per cent. of green and 50 per cent. of blue. Since, in order to make white, more of that color is required for which the eye is most sensitive, we may perhaps infer that Professor Maxwell was somewhat less sensitive to blue than these observers, although it should be remembered that the relative intensity of the blue and red in the solar spectrum is liable to undergo considerable fluctuations, so that where direct comparison of individual eyes is impossible, some uncertainty must remain.

We have selected for comparison with our results the following by Captain Abney (using a different photometric method), which we have here reduced to the normal scale. (See "Transmission of Sunlight through the Earth's Atmosphere," by Capt. W. de W. Abney, R. E., F. R. S.; Phil. Trans. R. Soc., vol. 178 (1887), A, pp. 274–276.) From the mean of the observations of July 1, July 5, and July 21, 1886, made with an average air-mass of 1.33 atmospheres, we obtain these photometric values for the normal spectrum:

λ =	0 .40	0$^{\mu}$.45	0$^{\mu}$.50	0$^{\mu}$.55	0$^{\mu}$.60	0$^{\mu}$.65	0$^{\mu}$.70
Light=	0.8	2.8	25.0	82.0	66.5	12.3	0.5

The general form of this curve agrees with that of S. P. L. (curve *a*, Plate III), showing a maximum sensitiveness near $\lambda=0^{\mu}.57$. The light curves of F. W. V. (curve *c*, Plate III) and of E. M. (curve *b*, Plate III) have their maxima respectively near $\lambda=0^{\mu}.52$ and $\lambda=0^{\mu}.53$.

Everything which has preceded has had reference to the *relative* luminous effects produced by *any* (moderate) constant quantity of energy. It may, however, be interesting to make the novel calculation as to the actual amount of energy required to make us *see*, and we can obtain an approximate estimate of this amount of energy as follows:

Actinometric measurements made during the progress of the photometric observations showed a solar radiation of 1.5 calories per square centimetre per minute. Of this amount of heat the slit (s_1), being 3^{cm}.4 high by 0^{cm}.01 wide, received the fraction 0.034. The visible spectrum (from A to H) included, according to the bolometer measures, about 21 per cent. of the total energy, the absorption of the lower infra-red by the great thickness of glass in the prism being large. We estimate that nearly 20 per cent. had been lost by reflection before the bolometer was reached. The spectrum formed had a length of 86^{mm} from A to H. The *average* energy which passed through the millimetre aperture of slit s_2 was, therefore (within these limits, and expressed as heat),

$$1^{cal}.5 \times 0.034 \times 0.21 \times 0.8 \times \frac{1}{86},$$

or, approximately, $\frac{1}{10{,}000}$ calorie, let us say 4,000 ergs, per minute.

At 1 metre from slit s_2, this energy is further spread out over an illuminated area of 28 square centimetres, of which the square centimetre of fine print, being placed at an angle of 45° with the path of the ray, occupies only about $\frac{1}{40}$. If a length of 1^{mm} of the standard spectrum receives an average energy of $\frac{1}{10,000}$ calorie per minute, the actual working part of the screen, consisting of the little square of fine print, will receive at a distance of 1 metre, $\frac{1}{400,000}$ calorie per minute. But this by no means gives the amount of energy requisite to produce vision, since the eye is able to receive a distinct visual impression in less than one-half second of time. We may say, therefore, that a luminous energy of $\frac{1}{50,000,000}$ calorie is sufficient to give a distinct view of the small square of figures in the brightest part of the spectrum, even after the immense loss of light by absorption and diffusion in the paper, which may amount to $\frac{19}{20}$ of the whole.

Even less light is needed to give the bare impression of luminosity. The sensitiveness of the human eye is, indeed, so extraordinary that the chief difficulty in measuring its power is to find means for sufficiently reducing the intensity of sunlight which are at the same time capable of even approximate numerical estimation. Out of numerous plans tried the following has given the most reliable result.

In front of the first slit, in the path of the rays from the siderostat, was placed a plate of smoked glass, whose transmission for different kinds of light was first photometrically measured and found to be—

For violet light ($\lambda=0^{\mu}.40$) transmission..... 0.000210
For green light ($\lambda=0^{\mu}.55$) transmission..... 0.000655
For red light ($\lambda=0^{\mu}.65$) transmission..... 0.002350

The photometer wheel was next interposed, its aperture being sometimes reduced until only 2 per cent. of the light received passed through it.

The slit was at first kept as near the standard width of $0^{mm}.1$ as possible; but it was afterward deemed best to secure the final adjustment for the *minimum visibile* at the slit, as it was evident on trial that the inaccuracy due to the varying loss by diffraction was small, compared with the inevitable uncertainty of the observer himself.

Finally, the larger part of the necessary reduction was secured by reducing the aperture of the collimating lens by means of a metal plate pierced by a minute aperture whose area, 0.00015 square centimetres, was 0.000003 of the fully illuminated area of the lens.

The aperture of the human eye, according to du Bois-Reymond's photograph (see Nature, May 3, 1888, p. 15), is about 0.7 square centimetres when fully expanded, or the same as that of the fore shortened disk of figures previously employed. The size of the light spot at the standard distance beyond slit s_2, when the minute aperture is placed over the collimating lens, is reduced so that about two-thirds of the light enters the eye placed 1 meter behind the 1^{mm} slit on which the spectrum is formed.

The following reductions of sunlight were needed in order to give a light which approximated to the *minimum visibile*, defining this to be, not the smallest light whose existence it is possible to suspect, or even to be reasonably certain of, but a light which is observed to vanish and reappear when silently occulted and restored by an assistant without the observer's knowledge.

Referred to the standard spectrum employed in the previous photometric work, the observer F. W. V. found:

Fraction of standard violet light ($\lambda=0^{\mu}.40$) required for certain vision $= 0.00021\times100\times0.000003=0.000000063$.

Fraction of standard green light ($\lambda=0^{\mu}.55$) required for certain vision $=0.000655\times0.033\times0.000003=0.0000000000655$.

Fractions of standard scarlet light ($\lambda=0^{\mu}.65$) required for certain vision $=0.00235\times2\times0.000003=0.0000000141$.

Fraction of standard crimson light ($\lambda=0^{\mu}.75$) required for certain vision $=10\times0.000003=0.00003$.

The measures were made on July 3 and 11, the sky being a fairly good milky blue and the sun within one hour of the meridian.

Assuming that the energy per millimetre of the standard spectrum was 0.000001 calorie per half second for the wave-lengths, $0^{\mu}.55$ and $0^{\mu}.75$, we have from Table I

For $\lambda=0^{\mu}.40$, energy$=5.3\div(20.7\times1\,000000)$ calorie.
For $\lambda=0^{\mu}.65$, energy$=22.2\div(20.7\times1\,000000)$ calorie.

by means of which, we reduce each of the above values to absolute measure, obtaining for the maximum value of the

Minimum visibile.

		Reciprocal of—		Reciprocal of—
Violet	$0^{\mu}.40$	63 000000 000000 calories	=	1 500000 ergs.
Green	$0^{\mu}.55$	15000 000000 000000 calories	=	360 000000 ergs.
Scarlet	$0^{\mu}.65$.....	66 000000 000000 calories	=	1 600000 ergs.
Crimson	$0^{\mu}.75$.....	33000 000000 calories	=	780 ergs.

Stating the rates of working in terms of horse-power we have

Minimum visibile.

		h. p.
Violet	$0^{\mu}.40$.....	0.000000 000000 00018000
Green	$0^{\mu}.55$	0.000000 000000 00000075
Scarlet	$0^{\mu}.65$.....	0.000000 000000 00017000
Crimson (near A)	$0^{\mu}.75$.....	0.000000 000000 34000000

The relative sensitiveness of the eye of the observer in question (F. W. V.) for the extreme red or violet, as compared with its power of detecting green light, appears to be somewhat less when determined by the method of *minimum visibile* than by the reading of fine print.

By the former we have

Sensitiveness violet ($\mu.40$) : green ($\mu.55$) = 1 : 240
scarlet ($\mu.65$) : green ($\mu.55$) = 1 : 230
crimson ($\mu.75$) : green ($\mu.55$) = 1 : 450 000

Photometry by the reading of fine print gave for the same observer

Violet, sensitiveness of eye = 0.104 000
Green, sensitiveness of eye = 5.790 000
Scarlet, sensitiveness of eye = 0.036 000
Crimson, sensitiveness of eye = 0.000 070

unity being the sensitiveness for yellow light; and the relative effect by this method is

Violet ($\mu.40$) : green ($\mu.55$) = 1 : 56
Scarlet ($\mu.65$) : green ($\mu.55$) = 1 : 160
Crimson ($\mu.75$) : green ($\mu.55$) = 1 : 83 000

The measurement of the *minimum visibile* is subject to variations of a much wider range than those of the photometric method and may perhaps be in error by 100 per cent.

The probable error of a series of ten readings of fine print, under the actual conditions of observation with a (feeble) standard luminosity, is determined for two of the observers as follows:

June 19, 1888.—Sky hazy blue; thin but uniform cirrus haze. Violet light ($\lambda=0^{\mu}.40$).

	F. W. V.	E. M.
	Per cent.	*Per cent.*
Probable error of one observation.....	5.53	7.69
Probable error of mean.....	1.75	2.44

June 20, 1888.—Sky, hazy blue with cumuli; haze not so dense as on the 19th, but possibly less uniform.

Orange-yellow light ($\lambda = 0^{\mu}.60$).

	F. W. V.	E. M.
	Per cent.	*Per cent.*
Probable error of one observation	1.76	2.51
Probable error of mean	0.56	0.80

Scarlet light ($\lambda = 0^{\mu}.65$).

	F. W. V.	E. M.
	Per cent.	*Per cent.*
Probable error of one observation	3.14	2.86
Probable error of mean	0.99	0.90

For a large part of the spectrum the probable error of a single reading does not exceed 4 per cent., but the error may considerably exceed this for the violet rays, *the eye requiring a much longer time to regain its sensitiveness for light of this color than for any other*, so that for measures in this region an hour's stay in the darkened room is none too much to develop the full power of an eye which has recently been exposed to the full sunshine.

TIME REQUIRED FOR VISION.

In connection with the photometric measures the time required for the perception of very faint colored lights was investigated. The method was an electrical one. There was automatic registration on a chronograph of the instant of exhibition, and determination of the instant of response as the observer pressed a key. The interval of course includes quite a train of distinct operations. According to Mendenhall (Am. Journ. of Sci., ser. 3, vol. 2, p. 156), that portion of the action of brain, nerve, and muscle which produces the mechanical effect, and which may be called automatic, takes place in certainly but little over one-tenth of a second. But the sensations which demand a conscious concentration of the attention, and especially those which require for their registration a decision of the judgment, occupy an interval several times as great. The perception of a light just at the verge of visibility probably involves an exercise of judgment, an answer to the question, "Do I see the light or do I not?" although the question may not be consciously propounded, and accordingly this kind of perception may be included in that class of combined sensation and mental operation which involves a choice.

Professor Mendenhall found for the time required to decide between red and white $0^{sec}.443$, and to decide between a circle and a triangle $0^{sec}.494$. We have found for the average of over 1,000 observations of the disappearance or reappearance of a very faint light (perhaps 20 times as bright as the faintest perceptible) $0^{sec}.507$, but corresponding measures with a moderately bright spectrum, the light being about 10,000 times as intense as that called "very faint," gave $0^{sec}.242$, a number which is intermediate between the times found by Professor Mendenhall for the appearance of a white card ($0^{sec}.292$ and that of an electric spark ($0^{sec}.203$). We may therefore conclude that distinct vision for a very faint light demands about one-half second of time, while the perception of light of ordinary brightness requires only about half that interval. It is possible that differences in the rapidity of the perception for lights of different colors might be detected on more exhaustive study, but none have been noted in these experiments other than those which were attributable to the variation of intensity.

It will be seen that quantitative measures of the effect upon the eye of different rays whose luminosity varied in the proportion of 200,000 : 1 were actually obtained, and that it would have been possible to considerably exceed these limits, especially when it is considered that the photo-

metric measures were confined to lights of feeble intensity. Since it is possible to look directly at the sun for so short a time as one-half second, it is certain that the eye, by the combined adaptability of the iris and retina, can perceive lights whose intensities vary in the ratio of 1 to 1 000 000000 000000.*

It will be understood that the writer does not profess any competence in physiological optics, and that the preceding observations and the conclusions reached from them are both to be understood from the purely physical point of view. This being premised, we will summarize the paper in the following conclusions:

The time required for the distinct perception of an excessively faint light is about one-half second. A relatively very long time is, however, needed for the recovery of sensitiveness after exposure to a bright light, and the time demanded for this restoration of complete visual power appears to be greatest when the light to be perceived is of a violet color.

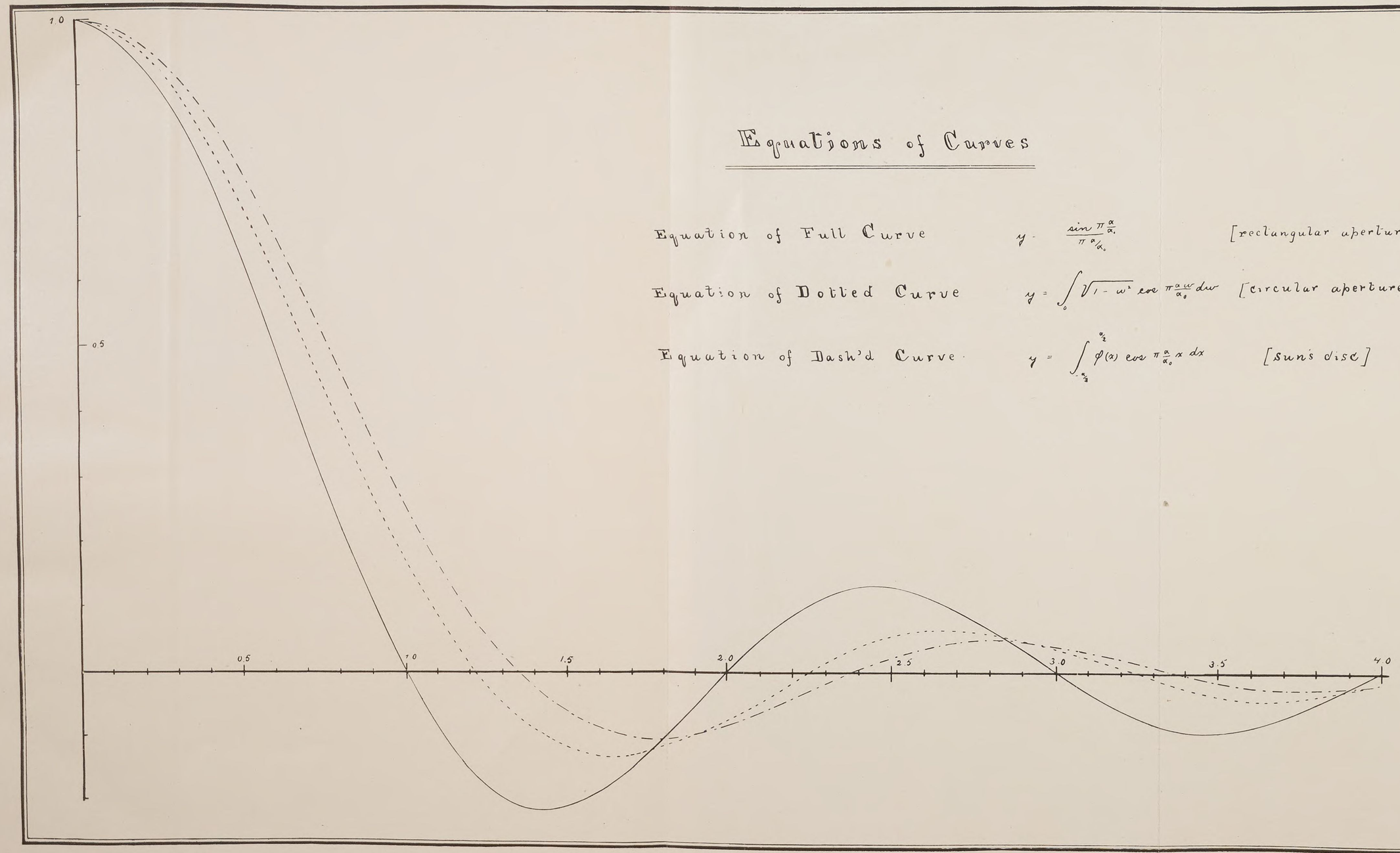
The amount of energy required to make us *see* varies enormously according to the color of the light in question. It varies considerably between eyes which may ordinarily be called normal ones, but an average from those of four persons gives the following proportionate result for seven points in the normal spectrum, whose wave-lengths correspond approximately with those of the ordinary color divisions, where unity is the amount of energy required to make us see light in the extreme red of the spectrum near A, and where the six preceding wave-lengths given correspond approximately to the six colors violet, blue, green, yellow, orange, red.

Color	Violet.	Blue.	Green.	Yellow.	Orange.	Red.	Crimson.
Wave-length	μ.40	μ.47	μ.53	μ.58	μ.60	μ.65	μ.75
Luminosity	1,600	62,000	100,000	28,000	14,000	1,200	1

It appears from this that the same amount of energy may produce at least 100,000 times the visual effect in one color of the spectrum that it does in another. If now it be inquired what the actual value of unity is, in ordinary measure, we are able to give this also with a fair approximation, and to say that the *vis viva* of the waves whose length is 0μ.75, being arrested by the ordinary retina, represents work done in giving rise to the sensation of the deepest red light of about 0.001 of an erg in one-half second.

I desire, in conclusion, to acknowledge the value of the aid I have received from Mr. F. W. Very, who has been my principal assistant in this research.

* It may be interesting to check this result by an entirely different method. The light of the sun is, according to Pickering, equal to that of a star of —25.5 stellar magnitude, or 4400 000000 times that of Sirius (mag. —1.4), which again is about 910 times that of a sixth-magnitude star, ordinarily considered the faintest visible to the naked eye. Here the light of the sun might appear to that of the *minimum visibile* as 1 to 4 000000 000000, but the difference is quite accounted for by the fact that the ratio by this latter method is found by an eye exposed in starlight, the former in *absolute* darkness.

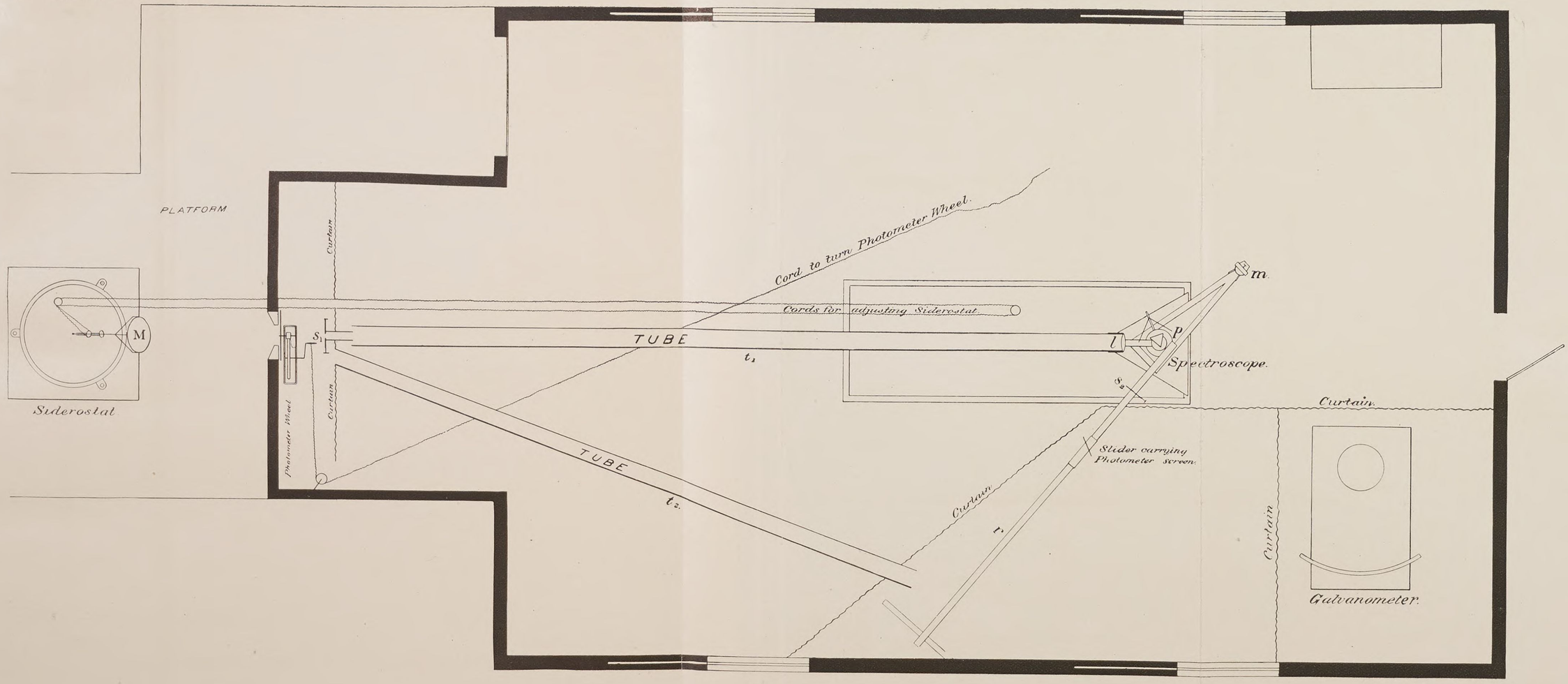


Equations of Curves

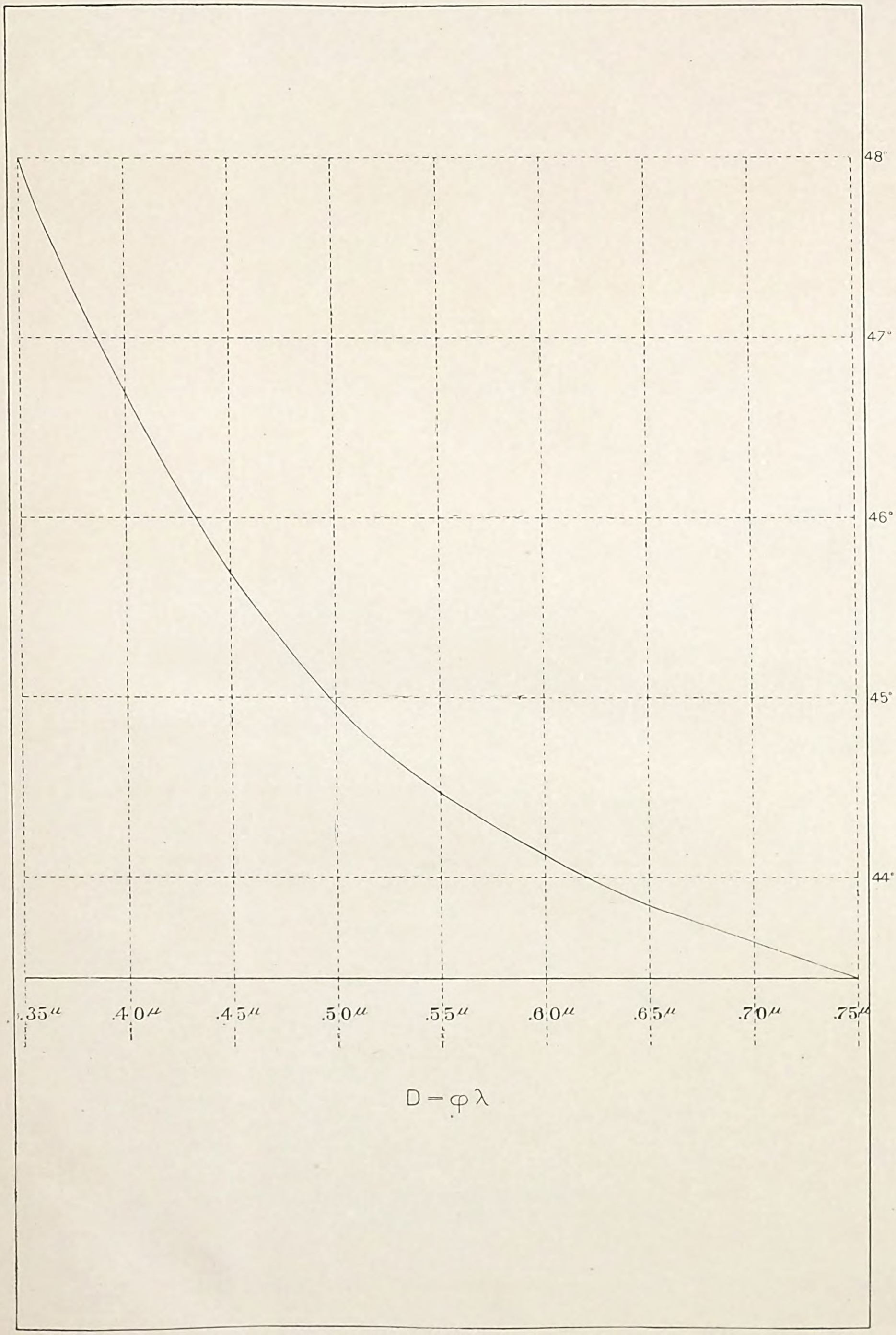
Equation of Full Curve $y = \frac{\sin \pi \frac{a}{a_0}}{\pi \frac{a}{a_0}}$ [rectangular aperture]

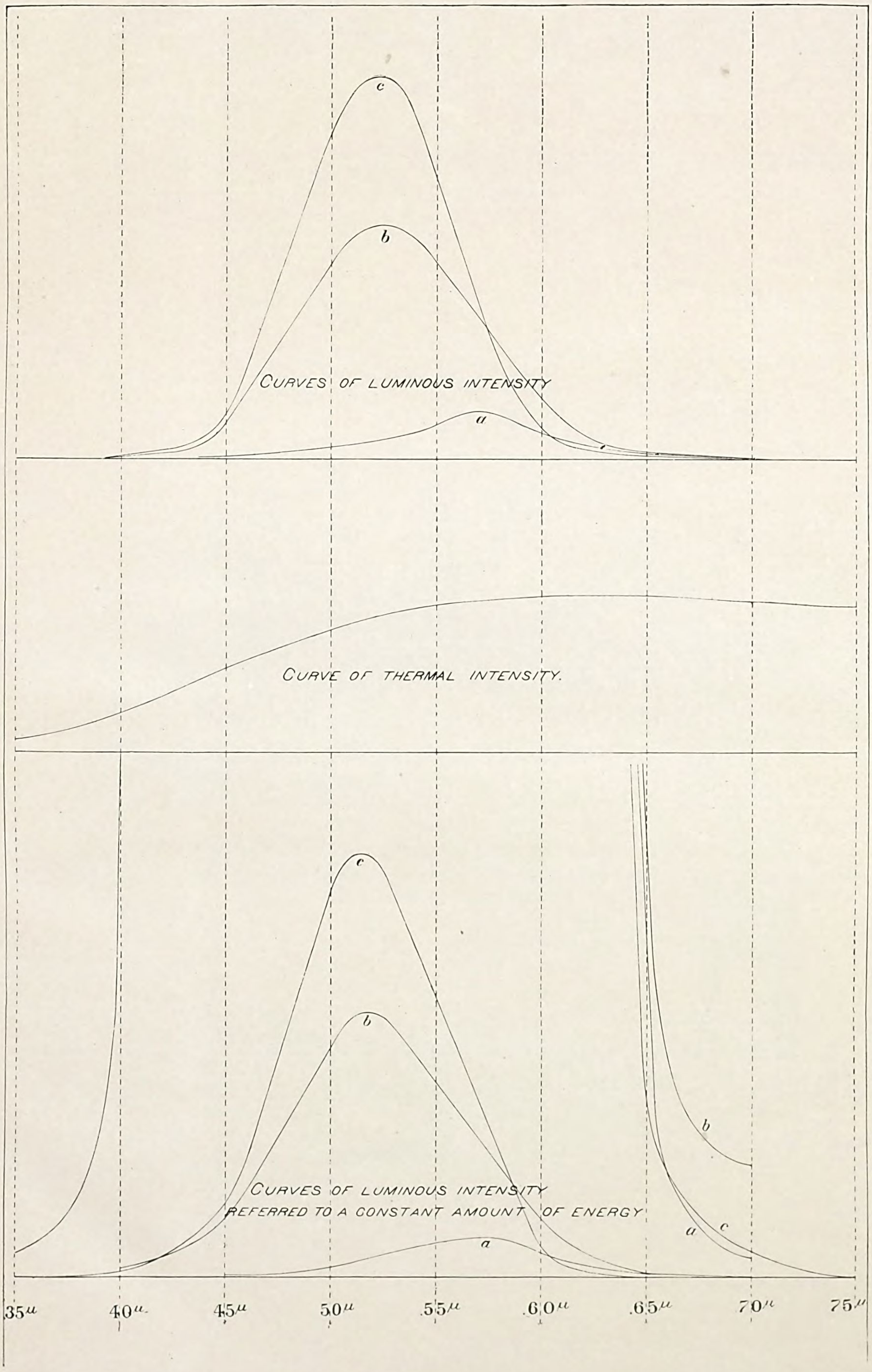
Equation of Dotted Curve $y = \int_0 \sqrt{1 - w^2}\, \cos \pi \frac{a w}{a_0}\, dw$ [circular aperture]

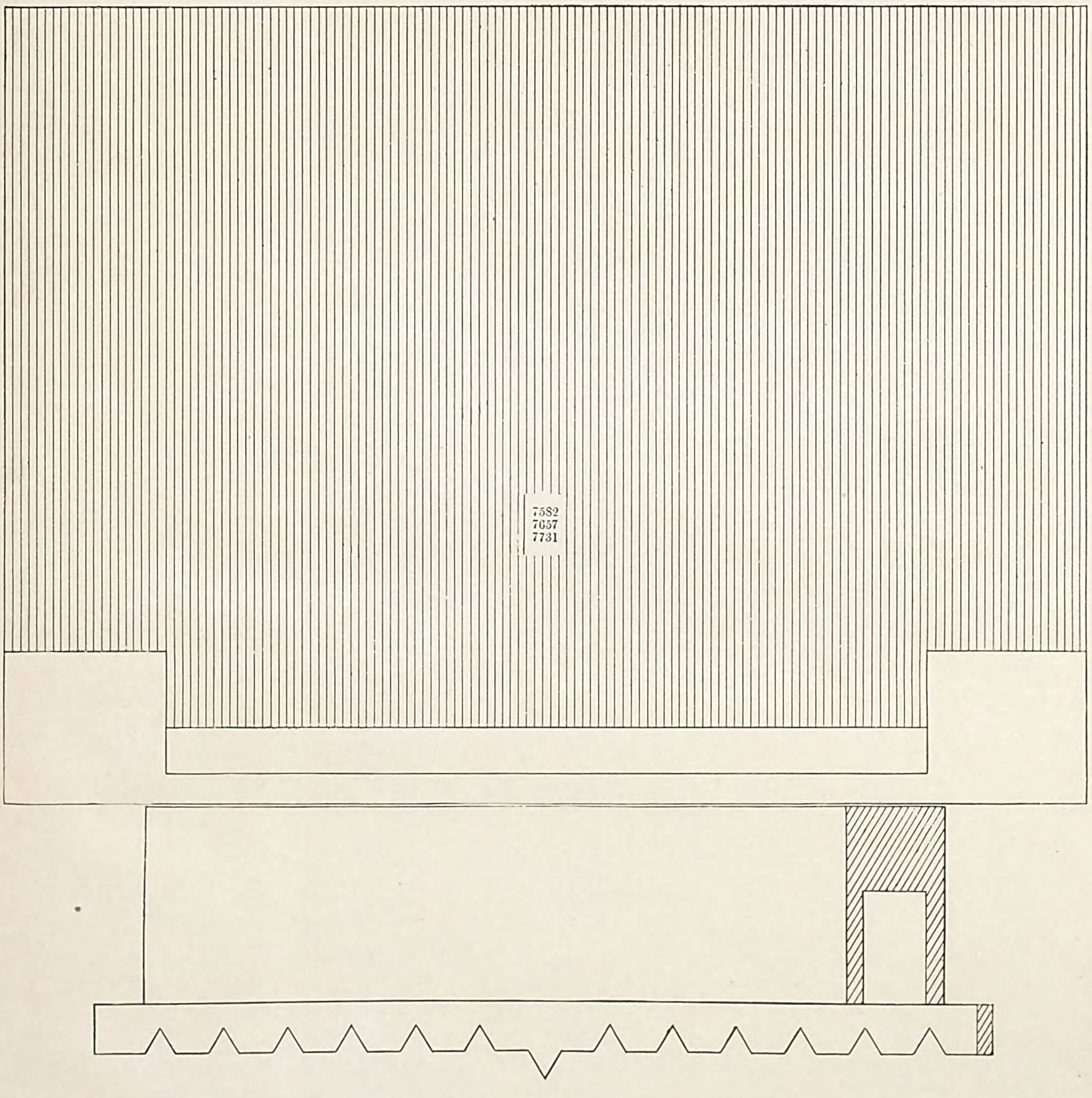
Equation of Dash'd Curve $y = \int_{-\frac{a_2}{2}}^{\frac{a_2}{2}} \phi(x) \cos \pi \frac{a}{a_0} x\, dx$ [sun's disc]



PLAN OF DARK-ROOM.


48"
47°
46°
45°
44°
.35μ
.40μ
.45μ
.50μ
.55μ
.60μ
.65μ
.70μ
.75μ
D = φ λ


c
b
a
CURVES OF LUMINOUS INTENSITY
CURVE OF THERMAL INTENSITY.
c
b
a
b
a
c
CURVES OF LUMINOUS INTENSITY
REFERRED TO A CONSTANT AMOUNT OF ENERGY
35μ
40μ
45μ
50μ
55μ
60μ
65μ
70μ
75μ



SCREEN. FULL SIZE.

NATIONAL ACADEMY OF SCIENCES.

VOL. V.

SECOND MEMOIR.

CONTRIBUTIONS TO METEOROLOGY.

CONTRIBUTIONS TO METEOROLOGY.

By Elias Loomis, LL.D.

MEAN ANNUAL RAINFALL FOR DIFFERENT COUNTRIES OF THE GLOBE.—CONDITIONS FAVORABLE TO RAINFALL; CONDITIONS UNFAVORABLE TO RAINFALL.—EXAMINATION OF INDIVIDUAL CASES OF RAINFALL IN THE UNITED STATES—IN EUROPE—OVER THE ATLANTIC OCEAN.—AREAS OF LOW PRESSURE WITHOUT RAIN.

203. When we attempt to analyze the phenomena of storms, we immediately find evidence of the operation of general causes which are not peculiar to any particular storm. This truth is illustrated by the tracks which storms pursue and by the unequal amounts of rain which are precipitated at different places. In the case of any particular storm it is difficult to decide how much influence is to be ascribed to general causes and how much to special causes. The influence of general causes is sometimes best exhibited by the averages derived from a large number of cases, by which means the peculiarities of particular storms are partly eliminated. With this object in view I have studied the average annual distribution of rain for the entire globe. A comparison of the mean annual rainfall for different localities shows unequivocally the influence of general causes quite distinct from the peculiarities of particular storms. These general causes must operate upon each storm, and a clear knowledge of their nature must assist us in explaining the phenomena of particular storms.

204. For the purpose of prosecuting this investigation I have labored to collect the results of rainfall observations for all portions of the earth's surface. Table LXXXII exhibits some of the results which I have collected. For those regions of the globe where only a few scattered observations have been found all known cases have been inserted in the table; but for those countries where the stations of observation are numerous only a small portion of the whole number have been retained. If I had included in the table the results for all known stations the list would have filled a large volume. The number of stations in the United States at which the rainfall has been measured is over 2,000; the total number of rain-gauges now regularly observed in Great Britain is about 2,200; in France the rainfall is measured at 1,500 stations, and there are numerous stations of observation in every country of Europe. In British India the rainfall has been measured at 464 stations, at many of which the observations have been continued for more than 20 years; in the islands of the Asiatic Archipelago belonging to Holland the rainfall is measured at 172 stations; in Australia the rainfall is measured at over 900 stations, and there are numerous stations of observation in Algeria, in South Africa, in the Argentine Republic, and elsewhere. The results of all these observations are graphically exhibited on Plate XXXIII by lines of equal rainfall. In order to avoid confusion and to render the main results more prominent I have represented only five gradations in the amount of rainfall. The first grade includes those stations at which the mean annual rainfall does not exceed 10 inches, and these regions are represented on the map by a light shade of yellow; the second grade includes those stations at which the mean annual rainfall exceeds 10 inches but is less than 25 inches, and these regions are represented on the map by a light shade of orange; the third grade includes stations having a rainfall

of from 25 to 50 inches, and these regions are represented by a light shade of green; the fourth grade includes stations having a rainfall of from 50 to 75 inches and are represented by a light shade of blue, and the fifth grade includes stations having a mean annual rainfall exceeding 75 inches and are represented by a light shade of red. All available observations have been consulted in drawing the lines of equal rainfall upon Plate XXXIII, but only a small part of them are contained in Table LXXXII.

The first column in Table LXXXII contains the reference number; column 2 gives the name of the station; columns 3 and 4 give the latitude of the station and its longitude reckoned from Greenwich; column 5 gives its elevation above the sea expressed in English feet. For many stations the elevation is not given, and where the figure 0 is inserted, it is to be understood as denoting that the station is but little elevated above sea level. Column 6 shows the mean annual rainfall expressed in English inches; column 7 shows the number of years of observations represented; and column 8 gives the authority for the results. In the last column considerable abbreviation has been found necessary. The following statement will afford an explanation of a large part of the abbreviations: Danish Met. Obs. refers to the Annuaire Meteorologique published by the Danish Institute; Schott's Rain Tables refers to the Tables of Rain and Snow published by the Smithsonian Institution in 1881; the Canada Mets. Obs. are derived chiefly from the annual reports of the Canada Meteorological Service; Lieut. W. A. Glassford refers to observations collected by him under the direction of the U. S. Signal Service. The observations were chiefly made by the railroad companies in the neighborhood of the Pacific coast. A large part of the observations have been published in the Ninth Report of the California Board of Health; the other observations for that region have been furnished in manuscript. The observations of the U. S. Signal Service are mostly to be found in the annual reports of the Chief Signal Officer. The Mexican Met. Obs. have been chiefly derived from a manuscript communication from Señor Mariano Bárcena. Hann's Met. Zeit. refers to Zeitschrift der Osterreichischen Gesellschaft für Meteorologie, edited by Dr. J. Hann. Journal Met. Soc. refers to the Quarterly Journal of the London Meteorological Society. Int. Obs. refers to the International Observations published by the U. S. Signal Service. Argentine Met. Obs. refers to Anales de la Oficina Meteorologica Argentina. Wild Regen-verhältnisse refers to Die Regen-verhältnisse des Russischen Reiches von H. Wild. Alexander Buchan refers to the Journal of the Scottish Meteorological Society for 1884. Delesse Bulletin Geogr. refers to Bulletin de la Société de Geographie, tome XVI. The Spanish Met. Obs. are derived chiefly from Anuario del Observatorio de Madrid; the Swiss Met. Obs. are derived from Annalen des Schweizerischen Meteorologischen Central-Anstalt. Italiano Ann. Met. refers to Annuario Meteorologico Italiano; Meteorology of India refers to the Annual Reports on the Meteorology of India by Henry F. Blanford; Meteorology of Japan refers to the publications of the (Japanese) Imperial Meteorological Observatory; Met. de France refers to the volumes of observations published by the Bureau Central Meteorologique de France. Todd's Met. Obs. are published in the Meteorological Observations made in South Australia and the Northern Territory; Frazer's Met. Obs. are derived chiefly from the volumes of Charles Todd; Russell's Met. Obs. are derived from Results of Rain Observations in New South Wales, by H. C. Russell; Ellery's Met. Obs. are derived from Results of Observations in Meteorology made at various localities in Victoria by Robert L. J. Ellery; Van Der Stok Obs. refers to Regenwaarnemingen in Nederlandsch-Indie, door Dr. J. P. Van der Stok.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe.*

NORTH AMERICA AND THE ADJACENT ISLANDS.

No.	Station.	Lat. N.	Long. W.	Altitude.	Rain.	Years Obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
1	Fort Conger	81 20	64 58	.....	3.88	2	Science, vol. v, p. 311.
2	Upernivik, Greenland	72 47	55 53	39	10.47	10	Danish Met. Obs.
3	Point Barrow	71 17	156 40	17	8.22	2	Exp. to P. Barrow, p. 332.
4	Jacobshavn, Greenland	69 13	50 55	41	8.79	10	Danish Met. Obs.
5	Fort Peel's River	67 32	134 30	.....	53.88	2½	Schott's Rain Tables.
6	Kingua Fjord	66 36	67 20	.....	10.51	1	German Pol. Ex., 1882–'83.
7	Grimsey, Iceland	66 34	18 3	8	16.42	10	Danish Met. Obs.
8	Stykkisholm, Iceland	65 5	22 46	37	26.32	10	Do.
9	Berufiord, Iceland	64 40	14 15	59	47.06	10	Do.
10	Kornok, Greenland	64 26	51 10	10	13.74	10	Do.
11	Godthaab, Greenland	64 11	51 46	37	24.26	10	Do.
12	Reikiavig, Iceland	64 9	20 0	36	28.94	7	Do.
13	Orebakke, Iceland	63 52	21 12	20	44.28	3	Do.
14	St. Michael's, Alaska	63 28	161 48	30	13.93	8	U. S. Signal Service.
15	Vestmannö, Iceland	63 26	20 18	26	51.39	3	Danish Met. Obs,
16	Fort Rae, British America	62 40	115 10	625	7.27	2	Canada Met. Obs.
17	Iviktut, Greenland	61 12	48 11	16	45.75	9	Danish Met. Obs.
18	Fort Chimo, Labrador	59 0	68 0	.....	28.05	1	U. S. Signal Service.
19	Fort Alexander, Alaska	58 57	158 18	.....	36.65	1	Do.
20	Ramah, Labrador	58 54	62 59	15	33.05	2	Canada Met. Obs.
21	St. Paul Kadiak, Alaska	57 47	152 20	22	72.90	1	Pacific Coast Pilot, p. 74.
22	St. Paul Island, Alaska	57 7	170 18	50	35.00	5	Pacific Coast Pilot, p. 91.
23	Sitka, Alaska	57 3	135 18	20	84.06	30	Pacific Coast Pilot.
24	York Factory, Hudson Bay	57 0	92 26	55	27.86	7	Canada Met. Obs.
25	Fort Wrangell, Alaska	56 16	132 29	30	60.50	3	Pacific Coast Pilot, p. 58.
26	Dunvegan, N. W. Ter	56 0	118 20	1,000	15.26	.....	Canada Met. Obs.
27	Fort Tongass, Alaska	54 46	130 30	25	113.31	2⅓	Pacific Coast Pilot, p. 55.
28	Unalashka, Alaska	53 53	166 32	13	109.74	3	U. S. Signal Service.
29	Edmonton, Manitoba	53 14	113 38	2,380	9.94	1	Canada Met. Obs.
30	Soda Creek, British Columbia	52 20	122 19	.....	10.92	2	Do.
31	Atka, Alaska	52 10	174 0	.....	84.54	2	U. S. Signal Service.
32	Belle Isle, Newfoundland	51 53	55 22	405	55.07	.....	Canada Met. Obs.
33	Moose Factory, Ontario	51 16	80 56	30	25.63	4	Do.
34	Clinton, British Columbia	51 6	121 48	2,978	8.75	2	Do.
35	Lillooet, British Columbia	50 42	122 2	.....	15.26	3	Do.
36	Kamloops, British Columbia	50 41	120 28	1,150	12.00	1	Do.
37	Gimli, N. W. Ter	50 37	96 58	723	26.75	1	Do.
38	Spence's Bridge, British Columbia	50 25	121 30	760	10.14	4	Do.
39	O. Kanagan, British Columbia	50 23	119 27	.....	13.20	1	Do.
40	Nicola Lake, British Columbia	50 16	120 43	2,100	11.99	3	Do.
41	Lytton, British Columbia	50 14	121 37	500	17.20	1	Do.
42	Minnedosa, Manitoba	50 14	99 47	1,766	28.33	.....	Do.
43	Meadow Lea, Manitoba	50 7	97 40	825	24.64	.....	Do.
44	Ossowa, Manitoba	50 6	98 15	.....	27.14	.....	Do.
45	Lit. Britain, Manitoba	50 6	96 57	.....	18.20	1	Do.
46	Poplar Heights, Manitoba	50 5	97 50	.....	25.45	2	Do.
47	Rockwood, Manitoba	50 5	97 12	.....	17.60	2	Do.
48	Winnipeg, Manitoba	49 52	97 0	.....	21.30	6½	Schott's Rain Tables.
49	Anticosti Island, Quebec	49 24	63 40	.....	40.96	2½	Do.
50	Hope, British Columbia	49 23	121 28	.....	53.60	2	Canada Met. Obs.
51	New Westminster, British Columbia.	49 12	122 53	.....	58.40	2	Do.
52	Matsqui, British Columbia	49 7	122 16	.....	61.10	1	Do.
53	Heart's Content, Newfoundland	47 53	53 21	.....	54.30	2	Do.
54	Harbor Grace, Newfoundland	47 42	53 15	60	47.30	4½	Schott's Rain Tables.
55	Saint John's, Newfoundland	47 34	52 42	170	56.40	10	Do.
56	Quebec	46 48	71 12	293	38.61	7	Do.
57	Bass River, New Brunswick	46 30	65 15	70	39.13	6	Do.
58	Glace Bay, Nova Scotia	46 10	60 0	30	53.66	6½	Do.
59	Sydney, Nova Scotia	46 4	60 12	27	54.01	7	Do.
60	Thurston, New Brunswick	46 0	67 0	.....	27.41	12	Do.
61	St. Martin, Quebec	45 32	73 46	118	53.19	9½	Do.
62	Montreal, Quebec	45 31	73 33	182	39.54	17	Do.
63	St. John, New Brunswick	45 22	66 4	135	52.95	14½	Do.
64	Wolfville, Nova Scotia	45 6	64 25	80	40.04	15	Do.
65	Halifax, Nova Scotia	44 39	63 35	8	53.25	9	Do.
66	Kingston, Ontario	44 13	76 24	294	28.74	5	Do.
67	Toronto, Ontario	43 39	79 23	342	34.34	34	Do.
68	Hamilton, Ontario	43 15	79 57	332	35.92	7	Do.
69	Windsor, Ontario	42 20	83 2	620	29 99	7	Do.
70	Fort Colville, Wash	48 42	118 2	1,963	14.06	11	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

NORTH AMERICA AND THE ADJACENT ISLANDS.

No.	Station.	Lat. N.	Long. W.	Altitude.	Rain.	Years Obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
71	San Juan Island, Wash	48 28	123 1	150	28.34	9	Schott's Rain Tables.
72	Tatoosh Light House	48 23	124 44	90	95.25	3	Do.
73	Neah Bay, Wash	48 22	124 37	40	110.05	9	Lieut. W. A. Glassford.
74	Port Townsend, Wash	48 7	122 45	16	19.23	14	Do.
75	Spokane Falls, Wash	47 40	117 25	1,909	20.78	6	Do.
76	Blakely, Wash	47 36	122 32	.....	46.39	9	Do.
77	Fort Steilacoom, Wash	47 11	122 34	300	38.92	12	Do.
78	Olympia, Wash	47 2	122 53	36	58.02	9	Do.
79	Cape Disappointment	46 17	124 3	30	71.24	6	Schott's Rain Tables.
80	Fort Canby, Wash	46 16	124 3	179	53.26	3	Lieut. W. A. Glassford.
81	Walla Walla, Wash	46 5	118 54	930	16.77	14	Do.
82	Fort Vancouver, Wash	45 40	122 30	50	38.37	17	Do.
83	Fort Stevens, Oregon	46 12	123 57	.....	78.57	6	Schott's Rain Tables.
84	Astoria, Oregon	46 11	123 48	52	76.48	23	Do.
85	Umatilla, Oregon	45 55	119 21	350	9.81	5	Lieut. W. A. Glassford.
86	Dalles, Oregon	45 33	120 50	350	21.96	12	Schott's Rain Tables.
87	Portland, Oregon	45 30	122 36	45	51.47	15	Lieut. W. A. Glassford.
88	Fort Yamhill, Oregon	45 21	123 15	.....	55.59	9	Schott's Rain Tables.
89	Fort, Hoskins, Oregon	45 6	123 26	.....	66.70	7	Do.
90	Eola, Oregon	44 57	122 54	500	37.72	5	Do.
91	Albany, Oregon	44 35	122 50	600	46.80	7	Lieut. W. A. Glassford.
92	Umpqua, Oregon	43 42	124 10	8	67.41	6	Do.
93	Empire City, Oregon	43 23	124 15	10	38.82	6	Lieut. W. A. Glassford.
94	Roseburgh, Oregon	43 10	123 20	511	34.62	9	Do.
95	Bandon, Oregon	43 7	124 25	43	62.79	9	Do.
96	Camp Harney, Oregon	43 0	119 0	.....	8.76	6	Schott's Rain Tables.
97	Fort Orford, Oregon	42 44	124 29	50	70.59	3	Do.
98	Camp Warner, Oregon	42 28	119 42	5,730	14.41	5	Do.
99	Ashland, Oregon	42 12	122 44	1,940	24.17	3	Lieut. W. A. Glassford.
100	Fort Benton, Mont	47 51	110 40	2,700	13.27	6	Schott's Rain Tables.
101	Fort Shaw, Mont	47 30	111 48	6,000	6.95	7	Do.
102	Fort Keogh, Mont	46 17	105 55	2,372	18.78	2	Do.
103	Virginia City, Mont	45 18	111 58	5,465	16.64	4	Do.
104	Fort Lapwai, Idaho	46 32	111 3	2,000	16.68	9	Do.
105	Boisé City, Idaho	43 40	116 6	2,750	16.19	6	Do.
106	Fort Laramie, Wyo	42 12	104 31	4,472	14.45	18	Do.
107	Fort Bridger, Wyo	41 20	110 23	6,656	8.43	13	Do.
108	Fort Sanders, Wyo	41 17	105 35	7,168	11.46	7	Do.
109	Cheyenne, Wyo	41 8	104 49	6,041	10.67	10	Do.
110	Camp Lincoln, Cal	41 50	124 5	.....	73.41	3	Do.
111	Fort Bidwell, Cal	41 50	120 10	4,680	19.15	20	Lieut. W. A. Glassford.
112	Crescent City, Cal	41 45	124 12	12	88.77	7	Do.
113	Yreka, Cal	41 43	122 38	2,635	15.85	14	Do.
114	Fort Jones, Cal	41 36	122 52	2,570	24.00	27	Do.
115	Fort Terwaw, Cal	41 30	123 52	.....	69.59	4	Do.
116	Fort Crook, Cal	41 7	121 29	3,390	23.18	9	Do.
117	Fort Gaston, Cal	41 1	123 34	.....	56.19	22	Do.
118	Blue Lake, Cal	40 53	124 0	.....	76.11	3	Do.
119	Weaverville, Cal	40 50	122 56	2,162	42.50	12	Do.
120	Humboldt, Cal	40 45	124 10	50	33.38	7	Do.
121	Hydesville, Cal	40 35	124 4	.....	38.49	3	Do.
122	Reading, Cal	40 28	122 13	674	36.66	12	Do.
123	Red Bluff, Cal	40 10	122 15	332	27.46	9	Do.
124	Tehama, Cal	40 2	122 7	220	15.39	16	Do.
125	Corning, Cal	39 57	122 3	.....	15.03	9	Do.
126	Meadow Valley, Cal	39 56	121 2	3,700	57.04	4	Do.
127	Orland, Cal	39 50	122 12	254	16.36	8	Do.
128	Camp Wright, Cal	39 48	123 17	.....	43.97	10	Do.
129	Chico, Cal	39 43	121 48	150	20.84	16	Do.
130	Cherokee, Cal	39 36	121 34	.....	44.93	13	Do.
131	Princeton, Cal	39 25	122 0	67	15.25	13	Do.
132	Emigrant Gap, Cal	39 18	120 42	5,230	51.41	17	Do.
133	Cisco, Cal	39 18	120 24	5,935	57.55	14	Do.
134	Nevada City, Cal	39 16	121 2	2,500	56.27	23	Do.
135	Colusa, Cal	39 13	121 57	45	16.99	15	Do.
136	Smartsville, Cal	39 12	121 17	800	32.18	10	Do.
137	Marysville, Cal	39 9	121 34	69	16.60	16	Do.
138	Ukiah, Cal	39 8	123 12	.....	32.92	10	Do.
139	Georgetown, Cal	38 59	120 48	2,500	60.04	14	Do.
140	Placerville, Cal	38 47	120 47	1,857	45.24	11	Do.
141	Woodland, Cal	38 45	121 47	45	16.59	15	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

NORTH AMERICA AND THE ADJACENT ISLANDS.

No.	Station.	Lat. N.	Long. W.	Altitude.	Rain.	Years Obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
142	Middletown, Cal	38 41	122 36	.....	41.85	7	Lieut. W. A. Glassford.
143	Folsom, Cal	38 40	121 10	197	23.09	15	Do.
144	Calistoga, Cal	38 39	122 31	331	31.83	14	Do.
145	Shingle Springs, Cal	38 37	120 55	1,530	34.25	20	Do.
146	Sacramento, Cal	38 34	121 26	81	20.32	37	Do.
147	Napa, Cal	38 20	122 16	20	23.36	10	Do.
148	Petaluma, Cal	38 16	122 38	10	22.32	15	Do.
149	Fairfield, Cal	38 15	122 58	11	20.10	15	Do.
150	Benicia, Cal	38 3	122 9	64	15.97	30	Do.
151	Stockton, Cal	37 57	121 15	20	13.54	16	Do.
152	Angel Island, Cal	37 51	122 26	50	21.85	18	Do.
153	Alcatraz Island, Cal	37 49	122 25	50	17.27	21	Do.
154	Oakland, Cal	37 48	122 15	25	24.54	13	Do.
155	San Francisco, Cal	37 48	122 26	60	24.25	37	Do.
156	Livermore, Cal	37 46	121 46	485	13.87	16	Do.
157	San José, Cal	37 29	121 54	94	12.95	13	Do.
158	La Grange, Cal	37 40	120 27	250	16.54	19	Do.
159	Los Banos, Cal	37 5	120 56	.....	7.54	11	Do.
160	Central Point, Cal	37 3	120 54	117	9.75	7	Do.
161	Fort Miller, Cal	37 0	119 40	402	19.00	8	Do.
162	Borden, Cal	36 56	120 0	274	9.27	12	Do.
163	Independence, Cal	36 56	118 8	3,957	5.97	13	Do.
164	Hollister, Cal	36 55	121 23	292	11.94	13	Do.
165	Firebaugh, Cal	36 52	120 28	150	8.48	14	Do.
166	Salinas, Cal	36 39	121 38	75	13.75	12	Do.
167	Monterey, Cal	36 37	121 52	42	14.96	12	Do.
168	Visalia, Cal	36 22	119 16	348	9.39	8	Do.
169	Tulare, Cal	36 13	119 20	289	6.09	13	Do.
170	Delano, Cal	35 44	119 15	319	6.34	11	Do.
171	San Luis Obispo, Cal	35 23	120 37	270	21.34	17	Do.
172	Sumner, Cal	35 20	119 0	422	5.02	12	Do.
173	Caliente, Cal	35 14	118 38	1,290	10.98	11	Do.
174	Mojave, Cal	35 10	118 10	2,751	4.94	8	Do.
175	Camp Cady, Cal	34 58	116 32	3,000	3.09	3	Do.
176	Fort Tejon, Cal	34 52	118 55	3,246	20.88	10	Do.
177	Santa Barbara, Cal	34 24	119 43	30	17.83	19	Do.
178	Colton, Cal	34 5	117 21	965	9.84	10	Do.
179	Los Angeles, Cal	34 3	118 15	299	17.64	9	Do.
180	Spadra, Cal	34 3	117 48	705	12.39	12	Do.
181	Riverside, Cal	33 59	117 21	1,030	9.37	5	Do.
182	Indio, Cal	33 41	116 13	12	2.32	9	Do.
183	Poway, Cal	33 6	117 5	.....	14.15	8	Do.
184	Mammoth Tank, Cal	33 3	115 16	265	2.21	9	Do.
185	Fort Yuma, Cal	32 44	114 36	141	3.86	17	Do.
186	San Diego, Cal	32 43	117 10	67	11.01	15	Do.
187	Camp McDermit, Nev	41 58	117 40	4,700	12.06	18	Do.
188	Camp McGarry, Nev	41 40	119 0	6,000	22.46	2	Do.
189	Camp Scott, Nev	41 34	117 30	.....	17.33	3	Do.
190	Tecoma, Nev	41 19	114 0	4,812	4.76	7	Do.
191	Otega, Nev	41 10	114 36	6,154	8.41	7	Do.
192	Toano, Nev	41 8	114 24	5,973	7.73	7	Do.
193	Wells, Nev	41 7	114 57	5,629	8.46	7	Do.
194	Golconda, Nev	41 0	117 29	4,385	6.44	7	Do.
195	Halleck, Nev	41 0	115 24	5,230	7.40	7	Do.
196	Winnemucca, Nev	40 58	117 43	4,358	8.87	8	Do.
197	Palisade, Nev	40 35	116 10	4,821	8.53	7	Do.
198	Wadsworth, Nev	39 38	119 16	4,077	3.80	7	Do.
199	Reno, Nev	39 32	119 50	4,497	4.67	16	Do.
200	Carson City, Nev	39 11	119 45	4,630	11.64	8	Do.
201	Pioche, Nev	37 57	114 26	6,220	6.31	5	Do.
202	Salt Lake City, Utah	40 46	111 54	4,354	16.97	10	U. S. Signal Service.
203	Camp Douglass, Utah	40 46	111 50	4,903	18.82	10	Schott's Rain Tables.
204	Camp Floyd, Utah	40 16	112 8	4,867	7.33	2	Do.
205	Harrisburgh, Utah	37 10	112 57	2,375	13.14	2	Do.
206	St. George, Utah	37 7	113 35	2,800	11.39	3	Do.
207	Denver, Colo	39 45	105 0	5,250	14.99	13	U. S. Signal Service.
208	Fort Lyon, Colo	38 6	115 9	4,000	11.90	9	Schott's Rain Tables.
209	Fort Massachusetts, Colo	37 32	105 23	8,365	17.23	5	Do.
210	Fort Garland, Colo	37 23	104 23	8,365	14.86	13	Do.
211	Fort Defiance, Ariz	35 43	109 10	6,500	14.21	8	Do.
212	Fort Mohave, Ariz	35 6	114 31	650	5.35	15	Lieut. W. A. Glassford.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

NORTH AMERICA AND THE ADJACENT ISLANDS.

No.	Station.	Lat. N.	Long. W.	Altitude.	Rain.	Years Obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
213	Prescott, Ariz	34 33	112 28	5,389	15.42	10	Lieut. W. A. Glassford.
214	Fort Verde, Ariz	34 24	111 53	3,100	13.02	11	Do.
215	Wickenburgh, Ariz	33 58	112 42	1,400	7.76	4	Do.
216	Fort Apache, Ariz	33 48	109 57	5,050	22.13	8	Do.
217	Fort McDowell, Ariz	33 40	111 40	.....	9.63	17	Do.
218	Phœnix, Ariz	33 18	112 0	1,120	6.97	10	Do.
219	San Carlos, Ariz	33 9	110 9	2,456	11.88	6	Do.
220	Fort Thomas, Ariz	33 4	110 2	2,710	11.12	7	Do.
221	Casa Grande, Ariz	32 54	111 42	1,396	3.37	5	Do.
222	Texas Hill, Ariz	32 46	113 34	353	3.27	6	Do.
223	Fort Grant, Ariz	32 39	109 57	4,856	18.07	16	Do.
224	Tucson, Ariz	32 14	110 56	2,369	12.06	11	Do.
225	Wilcox, Ariz	32 12	109 52	4,164	10.39	6	Do.
226	Fort Bowie, Ariz	32 10	109 50	3,757	15.90	7	Do.
227	Benson, Ariz	32 0	110 12	3,578	8.18	6	Do.
228	Fort Union, N. Mex	35 54	105 1	6,744	19.09	17	Schott's Rain Tables.
229	Santa Fé, N. Mex	35 41	106 10	7,106	14.91	19	Do.
230	Albuquerque, N. Mex	35 6	106 38	5,032	8.11	12	Do.
231	Fort Craig, N. Mex	33 38	107 0	4,619	11.06	15	Do.
232	Lordsburgh, N. Mex	32 20	108 39	4,247	8.18	5	Lieut. W. A. Glassford.
233	La Mesilla, N. Mex	32 17	106 48	3,900	7.32	3	Do.
234	Deming, N. Mex	32 16	107 44	4,334	8.29	4	Do.
235	Bismarck, Dak	46 48	100 38	1,704	21.27	9	U. S. Signal Service.
236	Duluth, Minn	46 48	92 8	664	34.09	12	Do.
237	Marquette, Mich	46 33	87 36	670	32.68	12	Do.
238	Escanaba, Mich	45 46	87 14	612	35.30	12	Do.
239	Alpena, Mich	45 5	83 28	608	38.21	11	Do.
240	Eastport, Me	44 55	66 54	61	49.02	10	Do.
241	St. Paul, Minn	44 53	93 5	801	29.76	11	Do.
242	Deadwood, Dak	44 22	103 34	4,630	26.47	5	Do.
243	Mount Washington, N. H	44 16	71 16	6,286	83.86	12	Do.
244	La Crosse, Wis	43 48	91 23	702	34.26	11	Do.
245	Portland, Me	43 40	70 16	45	38.67	12	Do.
246	Oswego, N. Y	42 28	76 35	304	36.59	12	Do.
247	Rochester, N. Y	43 8	77 51	589	37.32	11	Do.
248	Grand Haven, Mich	43 5	86 18	620	39.17	10	Do.
249	Milwaukee, Wis	43 3	87 54	697	34.15	12	Do.
250	Port Huron, Mich	42 58	82 29	633	35.26	9	Do.
251	Buffalo, N. Y	42 53	78 55	664	37.44	12	Do.
252	Yankton, Dak	42 45	97 30	1,228	28.82	10	Do.
253	Albany, N. Y	42 40	73 45	75	40.56	36	Schott's Rain Tables.
254	Thatcher's Island, Mass	42 36	70 34	48	48.81	8	U. S. Signal Service.
255	Dubuque, Iowa	42 30	90 44	665	39.41	10	Do.
256	Boston, Mass	42 21	71 4	142	40.61	38	Schott's Rain Tables.
257	Erie, Pa	42 7	80 10	681	42.39	10	U. S. Signal Service.
258	Chicago, Ill	41 52	87 35	661	37.57	12	Do.
259	Toledo, Ohio	41 40	83 32	651	33.21	12	Do.
260	Des Moines, Iowa	41 35	93 40	849	42.72	5	Do.
261	Davenport, Iowa	41 32	90 38	604	35.96	12	Do.
262	Cleveland, Ohio	41 30	81 47	690	39.09	12	Do.
263	Sandusky, Ohio	41 27	82 43	638	41.78	5	Do.
264	New London, Conn	41 22	72 9	47	48.19	12	Do.
265	Detroit, Mich	41 21	83 7	645	36.19	12	Do.
266	New Haven, Conn	41 17	72 57	104	45.44	27	Schott's Rain Tables.
267	Omaha, Nebr	41 16	96 0	1,113	35.82	12	U. S. Signal Service.
268	North Platte, Nebr	41 8	100 53	2,841	19.97	9	Do.
269	New York, N. Y	40 42	74 0	164	46.52	30	Schott's Rain Tables.
270	Pittsburgh, Pa	40 32	80 2	776	37.04	12	U. S. Signal Service.
271	Sandy Hook, N. J	40 28	74 1	29	51.26	10	Do.
272	Keokuk, Iowa	40 23	91 25	617	38.57	12	Do.
273	Columbus, Ohio	39 57	83 3	805	42.36	6	Do.
274	Philadelphia, Pa	39 57	75 10	52	43.29	52	Schott's Rain Tables.
275	Barnegat, N. J	39 48	74 9	20	50.18	11	U. S. Signal Service.
276	Springfield, Ill	39 48	89 48	644	47.42	5	Do.
277	Indianapolis, Ind	39 47	86 6	228	47.01	13	Do.
278	Atlantic City, N. J	39 22	74 25	13	43.23	11	Do.
279	Leavenworth, Kans	39 19	94 58	842	38.97	13	Do.
280	Baltimore, Md	39 18	76 38	45	42.87	22	Schott's Rain Tables.
281	Cincinnati, Ohio	39 6	84 26	620	42.96	42	Do.
282	Cape May, N. J	38 56	74 58	27	47.24	13	U. S. Signal Service.
283	Washington, D. C	38 53	77 1	106	38.05	37	Schott's Rain Tables.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

NORTH AMERICA AND THE ADJACENT ISLANDS.

No.	Station.	Lat. N.	Long. W.	Altitude.	Rain.	Years Obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
284	Pike's Peak, Colo	38 48	104 59	14,150	29.57	11	U. S. Signal Service.
285	Delaware Breakwater, Del	38 48	75 5	20	32.62	4	Do.
286	St. Louis, Mo	38 37	90 15	568	40.69	40	Schott's Rain Tables.
287	Louisville, Ky	38 18	85 52	530	49.04	12	U. S. Signal Service.
288	Chincoteague, Va	37 55	77 20	18	38.48	4	Do.
289	Dodge City, Kans	37 39	100 8	2,512	21.11	10	Do.
290	Lynchburgh, Va	37 30	79 2	646	42.57	13	Do.
291	Cairo, Ill	37 0	87 12	377	46.74	13	Do.
292	Cape Henry, Va	36 56	76 0	16	56.29	11	Do.
293	Norfolk, Va	36 51	76 19	54	51.62	14	Do.
294	Nashville, Tenn	36 11	86 53	507	53.66	13	Do.
295	Kitty Hawk, N. C	36 0	75 23	20	64.65	9	Do.
296	Knoxville, Tenn	35 56	83 58	980	53.87	14	Do.
297	Charlotte, N. C	35 13	80 51	838	54.10	6	Do.
298	Memphis, Tenn	35 7	90 7	321	56.10	13	Do.
299	Chattanooga, Tenn	35 4	85 15	783	59.84	6	Do.
300	Little Rock, Ark	34 40	92 12	298	55.67	6	Do.
301	Wilmington, N. C	34 11	78 10	74	57.79	14	Do.
302	Smithville, N. C	33 55	78 1	33	50.99	9	Do.
303	Atlanta, Ga	33 45	84 23	1,131	56.23	6	Do.
304	Augusta, Ga	33 28	81 54	185	49.56	14	Do.
305	Charleston, S. C	32 45	79 55	52	59.91	14	Do.
306	Shreveport La	32 30	93 45	205	54.11	13	Do.
307	Vicksburg, Miss	32 23	90 54	243	61.38	13	Do.
308	Montgomery, Ala	32 22	86 23	219	53.25	12	Do.
309	Savannah, Ga	32 5	81 8	87	52.69	14	Do.
310	El Paso, Tex	31 46	106 32	3,956	13.14	6	Do.
311	Concho, Tex	31 22	100 20	1,754	29.94	8	Do.
312	Stockton, Tex	30 50	102 50	3,063	20.09	7	Do.
313	Mobile, Ala	30 42	87 59	39	65.97	13	Do.
314	Pensacola, Fla	30 25	87 12	30	68.56	5	Do.
315	Jacksonville, Fla	30 24	80 40	23	55.31	13	Do.
316	New Orleans, La	29 58	90 7	52	55.17	30	Schott's Rain Tables.
317	Galveston, Tex	29 18	94 50	40	52.30	13	U. S. Signal Service.
318	Indianola, Tex	28 32	96 38	26	38.72	12	Do.
319	Cedar Keys, Fla	28 12	83 2	22	56.70	5	Do.
320	Rio Grande City, Tex	26 22	98 45	230	22.52	6	Do.
321	Brownsville, Tex	26 0	97 30	43	33.01	9	Do.
322	Key West, Fla	24 32	81 48	32	40.12	14	Do.
323	Chihuahua, Mexico	28 38	106 30	4,640	25.44	3	Schott's Rain Tables.
324	Matamoras, Mexico	25 52	97 28	131	36.74	6	Do.
325	Monterey, Mexico	25 40	99 54	1,316	29.29	1	Mexican Met. Obs.
326	Saltillo, Mexico	25 25	100 36	5,357	19.43	1	Do.
327	Nieves, Mexico	23 38	103 43	.....	14.45	1	Do.
328	Mazatlan, Mexico	23 11	106 24	249	36.99	7	Do.
329	Zacatecas, Mexico	22 46	102 32	8,189	18.36	4	Do.
330	San Luis Potosi, Mexico	22 9	100 57	6,201	15.68	7	Do.
331	Pinos, Mexico	22 9	100 34	7,936	15.97	1	Do.
332	Aguas Calientes, Mexico	21 53	102 16	6,106	23.41	5	Do.
333	Pabellon, Mexico	21 50	102 16	6,314	19.74	16	Do.
334	Tepic, Mexico	21 22	104 52	3,458	42.90	7	Do.
335	Lagos, Mexico	21 21	101 54	6,339	34.12	1	Do.
336	Huejutta, Mexico	21 9	99 44	1,234	45.88	3	Do.
337	Leon, Mexico	21 7	101 40	5,901	28.44	9	Do.
338	Guanaxuato, Mexico	21 1	101 14	6,761	30.16	4	Do.
339	Tuxpan, Mexico	21 0	97 20	.....	57.00	5	Do.
340	Jalisco, Mexico	20 55	105 12	.....	49.41	1	Do.
341	Guadalajara, Mexico	20 41	103 19	5,141	35.36	7	Do.
342	Queretaro, Mexico	20 36	100 22	6,070	22.40	16	Do.
343	Merida, Mexico	20 29	89 35	.....	35.95	1	Do.
344	Tekax, Mexico	20 17	89 35	.....	45.52	1	Do.
345	Campeche, Mexico	19 51	90 30	28	32.80	1	Do.
346	San Juan del Rio, Mexico	19 49	99 46	6,483	19.71	3	Do.
347	Teziutlan, Mexico	19 49	97 22	6,503	60.28	5	Do.
348	Huchuetoca, Mexico	19 49	99 12	7,520	89.88	2	Do.
349	Morelia, Mexico	19 42	101 6	6,365	31.07	2	Do.
350	Patzcuaro, Mexico	19 31	101 30	7,015	45.62	2	Do.
351	San Jacinto, Mexico	19 27	99 9	.....	21.83	2	Do.
352	Mexico City, Mexico	19 26	99 7	7,489	25.74	20	Do.
353	Buena Vista, Mexico	19 19	98 47	7,218	23.77	21	Do.
354	Toluca, Mexico	19 17	99 39	8,612	26.69	2	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

NORTH AMERICA AND THE ADJACENT ISLANDS.

No.	Station.	Lat. N.	Long. W.	Altitude.	Rain.	Years Obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
355	Mirador, Mexico	19 15	96 40	3,600	83.86	12	Mexican Met. Obs.
356	Colima, Mexico	19 12	103 40	1,664	41.45	12	Do.
357	Vera Cruz, Mexico	19 12	96 2	23	174.62	10	Mayer's Mexico, etc.
358	Puebla, Mexico	19 3	98 11	7,112	46.86	10	Mexican Met. Obs.
359	Cuernavaca, Mexico	18 55	99 9	5,107	44.91	2	Do.
360	Cordoba, Mexico	18 53	96 51	2,749	111.72	4	Do.
361	Orizaba, Mexico	18 51	96 58	4,026	77.94	3	Do.
362	Tlacotalpam, Mexico	18 37	95 38	11	71.80	2	Do.
363	Frontera, Mexico	18 32	92 40	12	72.51	2	Do.
364	Carmen, Mexico	18 26	97 21	.....	22.21	1	Do.
365	Belize, Mexico	17 29	88 13	.....	79.30	7	Schott's Rain Tables, etc.
366	Oaxaca, Mexico	17 3	97 2	5,072	28.16	3	Mexican Met. Obs.
367	Yxta Comitan, Mexico	17 0	93 13	576	185.79	1	Do.
368	Llano Grande, Mexico	16 48	99 27	233	34.74	1	Do.
369	Comitan, Mexico	16 21	92 34	.....	63.28	1	Do.
370	Guatemala, Guatemala	14 40	90 30	.....	54.68	3	Schott's Rain Tables.
371	Bluefields, Nicaragua	12 0	83 43	.....	101.48	2	Int. Bulletin.
372	Rivas, Nicaragua	11 26	85 47	150	56.13	5	Do.
373	Heredia, Costa Rica	10 0	84 9	3,837	63.69	3	Hann's Met. Zeit.
374	San José, Costa Rica	9 56	84 7	3,757	60.62	14	Do.
375	Aspinwall, Panama	9 23	79 53	7	121.60	6	Schott's Rain Tables.
376	St. George's, Bermuda	32 23	64 40	123	55.15	15	Do.
377	Nassau, Bahamas	25 5	77 21	80	46.75	3	Do.
378	Havana, Cuba	23 9	82 23	63	46.46	25	Schott's Rain Tables, etc.
379	Matanzas, Cuba	23 2	81 38	50	55.29	1	Do.
380	Honolulu, Sandwich Islands	21 16	157 59	.....	22.00	.....	Guyot's Ph. Geog.
381	Santiago de Cuba	19 55	75 50	21	32.51	2	Int. Bulletin.
382	Cape Haitien, St. Domingo	19 43	72 13	.....	127.89	.....	Berghaus Ph. Atlas.
383	Port au Prince, St. Domingo	18 37	72 17	171	61.17	4½	Schott's Rain Tables.
384	Tivoli, St. Domingo	18 35	70 0	.....	107.47	2	Dove Beiträge.
385	Leogane, St. Domingo	18 30	72 30	.....	150.00	.....	Malte Brun. Geog.
386	Sombrero, Virgin Island	18 37	63 27	45	16.85	2	Schott's Rain Tables.
387	Tortola, Virgin Island	18 20	64 32	916	65.17	.....	Berghaus Ph. Atlas.
388	St. Thomas	18 21	64 56	131	55.18	3	Schott's Rain Tables.
389	San Juan, Porto Rico	18 26	65 39	.....	55.99	9	Int. Bulletin, etc.
390	Navassa	18 25	75 3	77	49.73	2	Int. Bulletin.
391	Philipsburg, St. Martin	18 5	63 3	.....	86.32	3	Schott's Rain Tables.
392	Castleton, Jamaica	18 9	76 50	700	106.61	4	Journal Met. Soc., v. 4.
393	Chincona, Jamaica	18 3	76 40	5,100	104.83	5	Do.
394	New Castle, Jamaica	18 3	76 44	3,974	100.01	5	Do.
395	Monaltrie, Jamaica	18 1	76 50	250	39.29	5	Do.
396	Mandeville, Jamaica	18 1	77 32	2,130	86.58	7	Do.
397	Kingston, Jamaica	17 58	76 50	50	35.79	6	Do.
398	Morant Point, Jamaica	17 56	76 28	.....	64.58	7	Do.
399	Santa Cruz	17 45	64 50	7	44.60	22	Hann's Zeit.
400	Antigua	17 10	61 48	.....	47.85	5	Dove Beiträge.
401	Pointe à Pitre, Guadaloupe	16 16	61 32	.....	71.62	19	Do.
402	Cafeiere de Perou, Guadaloupe	16 5	61 45	.....	126.74	19	Do.
403	Matouba, Gaudaloupe	16 5	61 50	4,000	292.33	1	Compt. Rend., v. 7.
404	Martinique	14 50	61 3	.....	86.93	.....	Gehler's Ph. Wört.
405	St. Vincent	13 15	61 18	.....	78.17	6	Dove Beiträge.
406	Bridgetown, Barbadoes	13 4	59 37	.....	55.61	30	Haughton Ph. Geog.
407	Grenada	12 9	61 48	.....	107.73	3	Dove Beiträge.

SOUTH AMERICA AND THE ADJACENT ISLANDS.

408	Curaçao Island	12 15	69 20	.....	26.64	.....	Berghaus Ph. Atlas.
409	Caracas, Venezuela	10 31	66 55	2,923	96.19	2	Schott and Dove.
410	Trinidad	10 28	60 28	.....	62.92	.....	Berghaus Ph. Atlas.
411	Cumana, Venezuela	10 27	64 15	.....	19.04	⅙	Humboldt.
412	La Baja, Colombia	7 22	72 30	.....	54.10	6	Proc. Br. Met. Soc.
413	Georgetown, British Guiana	6 50	58 4	.....	95.03	11	Sandeman's Obs.
414	Demerara, British Guiana	6 45	58 2	.....	156.72	.....	Berghaus Ph. Atlas.
415	Puerto Berrio, Colombia	6 22	74 28	542	97.02	5	Int. Obs.
416	Madellin, Colombia	6 15	75 35	4,876	63.36	2	Do.
417	Rustenburg, Dutch Guiana	6 0	55 0	.....	97.37	4	Schott's Rain Tables.
418	Paramaribo, Dutch Guiana	5 49	55 13	6	107.95	12	Int. Obs., etc.
419	Catharina, Dutch Guiana	5 48	56 47	.....	79.15	5	Schott's Rain Tables.
420	Marmato, Colombia	5 33	76 0	4,678	90.00	15	Proc. Br. Met. Soc.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

SOUTH AMERICA AND THE ADJACENT ISLANDS.

No.	Station.	Lat. N.	Long. W.	Altitude.	Rain.	Years Obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
421	Cayenne, French Guiana	4 56	52 30	.....	129.12	10	Dove Beiträge.
422	Bogota, Colombia	4 40	74 42	8,958	43.62	10	Int. Obs., etc.
423	Buenaventura, Colombia	3 50	76 55	18	245.94	1	Int. Obs.
424	Para, Brazil	1 27	48 37	.....	70.42	4	Dr. F. M. Dreinert.
425	St. Luis de Maranhao	2 31	44 18	.....	280.00	1	Humboldt, 5, 270.
426	Manaos, Brazil	3 8	60 0	121	55.12	1	Dr. F. M. Dreinert.
427	Fortalera, Ceara	3 42	38 29	.....	58.62	28	W. M. Roberts.
428	Parahyba, Brazil	7 6	34 55	406	38.02	1	Dr. F. M. Dreinert.
429	Pernambuco, Brazil	8 4	34 52	11	117.00	8	Do.
430	Victoria, Brazil	8 9	35 27	528	41.36	7	Do.
431	Jagueira, Brazil	8 10	35 57	.....	73.20	3	Dr. W. H. McGrath.
432	San Antonio, Brazil	9 5	64 0	.....	91.26	1	Hann's Zeit., 15.
433	Colonia Isabel, Brazil	8 45	35 42	751	40.83	6½	Dr. F. M. Dreinert.
434	San Anna do Sobradiuho	9 26	40 47	1,053	14.63	3	Do.
435	San Bento das Lages	12 37	38 40	98	86.93	5	Do.
436	Bahia, Brazil	12 58	38 32	213	95.14	5	Do.
437	Uberaba, Brazil	19 44	48 7	2,460	61.46	3	Do.
438	Sabara, Brazil	19 54	44 28	2,280	64.45	25	W. M. Roberts.
439	Congo Socco, Brazil	19 59	43 33	3,570	115.74	2	Dr. F. M. Dreinert.
440	Itabira do Campo	20 15	43 55	2,733	51.35	1	Do.
441	Queluz, Brazil	20 40	44 17	3,222	56.81	1⅜	Do.
442	Rio de Janeiro, Brazil	22 54	43 8	209	44.49	35	Imp. Observatorio.
443	San Paulo, Brazil	23 36	46 37	2,393	58.83	5	Dr. F. M. Dreinert.
444	Serra do Cubatao	23 45	46 30	2,625	140.82	15	Henry B. Joiner.
445	Santos, Brazil	23 56	46 17	95	98.54	15	Dr. F. M. Dreinert.
446	Joinville, Brazil	26 19	53 48	.....	89.57	2	Hann's Zeit., 13.
447	Pelotas, Brazil	31 47	52 19	54	38.20	6	Hann's Zeit., 19.
448	Salta, Rep. Argentine	24 46	65 27	3,944	24.94	6	Angentine Met. Obs.
449	Villa Occidental, Rep. Argentine	25 6	57 39	499	72.28	3	Do.
450	Asuncion, Paraguay	25 16	57 40	322	65.67	1	Do.
451	Villa Formosa, Rep. Argentine	26 13	58 5	328	72.71	3	Do.
452	Tucuman, Rep. Argentine	26 51	65 29	1,526	35.41	4	Do.
453	Corrientes, Rep. Argentine	27 28	58 56	253	52.36	8	Do.
454	Pilciao, Rep. Argentine	27 36	66 36	2,644	5.16	7	Do.
455	Santiago del Estero, Rep. Arg	27 48	64 23	702	27 71	7	Do.
456	Catamarca, Rep. Argentine	28 20	66 15	1,827	10.20	2	Do.
457	Villa Argentina, Rep. Argentine	29 5	68 0	3,691	10.76	1	Do.
458	Goya, Rep. Argentine	29 9	59 22	210	46.20	6	Do.
459	Rioja, Rep. Argentine	29 20	67 22	1,772	11.94	3	Do.
460	Curuzo-Cuatia, Rep. Argentine	29 53	58 9	197	51.45	1	Do.
461	Villa Hernandarias	31 10	59 41	190	39.35	6	Do.
462	Cordoba, Rep. Argentine	31 25	64 11	1,440	27.20	10	Do.
463	Concordia, Rep. Argentine	31 25	58 2	200	46.12	3	Do.
464	San Juan, Rep. Argentine	31 30	68 20	2,172	2.85	6	Do.
465	Parana, Rep. Argentine	31 44	60 24	256	36.78	6	Do.
466	Fraile Muerto, Rep. Argentine	32 34	62 37	459	35.69	2	Do.
467	San Jorge, Uruguay	32 45	56 10	.....	43.60	4	Do.
468	Mendoza, Rep. Argentine	32 53	68 52	2,559	7.97	5	Do.
469	Rosario, Rep. Argentine	32 57	60 39	128	38.51	5	Do.
470	San Luis, Rep. Argentine	33 19	66 20	2,493	21.81	4	Do.
471	Nueva Palmira, Rep. Argentine	33 52	58 16	49	27.22	4	Do.
472	S. Anto. de Areco, Rep. Argentine	34 12	59 30	141	31.36	3	Argentine Met. Obs.
473	Tatay, Rep. Argentine	34 16	59 54	367	33.79	6	Do.
474	Buenos Aires, Rep. Argentine	34 36	58 21	72	34.07	17	Do.
475	Chacra de Matanzas	34 44	58 26	69	36.59	5	Do.
476	Montevideo, Uruguay	34 54	56 13	39	43.57	10	Hann's Zeit., 11.
477	Salado, Rep. Argentine	35 44	59 6	49	30.95	4	Argentine Met. Obs.
478	Dolores, Rep. Argentine	36 19	58 14	33	33.28	4	Do.
479	Cape S. Antonio, Rep. Argentine	36 31	56 36	.....	32.26	27	Jo. Scot. Met. Soc., 7.
480	Tandil, Rep. Argentine	37 17	59 10	650	34.44	4	Argentine Met. Obs.
481	Bahia Blanca, Rep. Argentine	38 45	62 11	62	19.25	20	Do.
482	Chubut, Rep. Argentine	43 18	65 15	98	16.38	2	Do.
483	Quito, Ecuador	0 14	78 45	9350	46.58	1	Hann's Zeit., 16.
484	Antisana, Ecuador	0 21	78 6	13521	94.08	1	Hann's Zeit., 14.
485	Yquitos, Peru	3 44	73 8	320	103.28	1	Schott's Rain Tables.
486	Lima, Peru	12 3	77 2	499	8.86	1	Hann's Zeit., 6.
487	Cochahamba, Bolivia	17 18	65 58	.....	21.26	.....	Woeikoff Klim. d. Erde.
488	Atacama, Chili	22 36	68 40	.....	0	.....	Mühry Ubersicht.
489	Caldera, Chili	27 3	70 50	82	0	1	Hann's Zeit., 8.
490	Copiapo, Chili	27 38	70 38	82	0.32	4	Hann's Zeit., 11.
491	La Serena, Chili	29 56	71 16	82	0.51	4	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

SOUTH AMERICA AND THE ADJACENT ISLANDS.

No.	Stations.	Lat. N.	Long. W.	Altitude.	Rain.	Years Obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
492	Valparaiso, Chili	33 6	71 40	151	13.50	5	Hann's Zeit., 11.
493	Santiago, Chili	33 28	70 48	1919	14.10	19	Do.
494	Talca, Chili	35 26	71 46	344	19.87	4	Do.
495	Cencepcion, Chili	36 49	73 9	33	93.15	2	Do.
496	Corral, Chili	39 53	73 17	33	99.68	3	Do.
497	Valdivia, Chili	39 57	73 28	42	115.49	19	Do.
498	Puerto Montt., Chili	41 30	72 52	33	96.37	10	Do.
499	Ancud, Chili	41 51	72 1	49	52.01	3	Do.
500	Port Stanley	51 41	57 51	33	20.33	3	Argentine Met. Obs.
501	Punta Arenas	53 12	70 56	33	22.55	8	Hann's Zeit., 11.
502	South Georgia	54 31	36 0	.....	38.91	1	German Pol. Ex. 1882.
503	Ushuaia	54 53	68 10	98	20.57	4	Argentine Met. Obs.
504	Orange Bay	55 31 S	68 5	39	53.52	1	French Pol. Ex., 1882.

EUROPE AND THE ADJACENT ISLANDS.

505	Spitzbergen	78 28 N	15 44 E	.....	7.20	1	Wild Regen-verhältn.
506	Jan Mayen	70 50	8 28W	.....	19.10	1	Do.
507	Sodankyloe	67 27	26 36 E	.....	10.20	2	Do.
508	Alten, Norway	69 58	23 17	43	10.55	9	Do.
509	Syd-varanger, Norway	69 40	30 11	66	13.62	7	Do.
510	Tromso, Norway	69 39	18 58	39	35.91	10	Do.
511	Bodo, Norway	67 17	14 24	33	31.78	11	Do.
512	Bruno, Norway	65 28	12 14	36	32.72	11	Do.
513	Christiansund, Norway	63 7	7 45	49	35.71	20	Do.
514	Roros, Norway	62 35	11 23	2106	15.32	7	Do.
515	Aalesund, Norway	62 29	6 9	33	39.29	18	Do.
516	Dowre, Norway	62 5	9 8	2110	13.34	15	Do.
517	Domsten, Norway	61 53	5 40	36	70.71	7	Do.
518	Floro, Norway	61 36	5 2	23	69.69	11	Do.
519	Leirdal, Norway	61 6	7 27	16	12.64	9	Do.
520	Bergen, Norway	60 24	5 20	49	67.72	19	Do.
521	Ullensvang, Norway	60 22	6 41	36	40.27	7	Do.
522	Christiania, Norway	59 55	10 45	135	22.72	20	Do.
523	Skudesnas, Norway	59 9	5 16	36	42.64	20	Do.
524	Sandosund, Norway	59 5	10 28	43	22.48	20	Do.
525	Mandal, Norway	58 2	7 27	56	45.55	20	Do.
526	Jockmock, Sweden	66 36	19 50	925	15.12	.....	Do.
527	Haparanda, Sweden	65 51	24 11	30	16.54	.....	Do.
528	Pitea, Sweden	65 19	21 30	30	17.06	.....	Do.
529	Umea, Sweden	63 50	20 17	39	22.67	.....	Do.
530	Hernosand, Sweden	62 38	17 57	46	20.67	.....	Do.
531	Upsala, Sweden	59 52	17 38	79	21.16	.....	Do.
532	Stockholm, Sweden	59 20	18 4	157	16.37	.....	Do.
533	Stromstad, Sweden	58 56	11 11	30	25.21	.....	Do.
534	Wenersborg, Sweden	58 23	12 20	177	29.32	.....	Do.
535	Gothenburg, Sweden	57 42	11 58	23	31.07	.....	Do.
536	Halmstad, Sweden	56 40	12 51	33	28.74	.....	Do.
537	Kalmar, Sweden	56 40	16 21	125	13.37	.....	Do.
538	Skagen, Denmark	57 44	10 38	10	21.97	.....	Do.
539	Tarm, Denmark	55 53	8 31	23	26.89	.....	Do.
540	Copenhagen, Denmark	55 41	12 36	43	22.01	.....	Do.
541	Vejle, Denmark	55 36	9 36	.....	29.76	.....	Do.
542	Ryslinge, Denmark	55 15	10 33	.....	25.87	.....	Do.
543	Nowaja Semlja, Russia	72 30	52 42	33	12.20	2	Do.
544	Kola, Russia	68 53	33 1	33	7.92	5	Do.
545	Simajaja, Russia	65 41	40 14	33	13.34	3	Do.
546	Kem, Russia	64 57	34 39	33	14.12	19	Do.
547	Archangelsk, Russia	64 33	40 32	33	15.61	17	Do.
548	Powenez, Russia	62 51	34 49	131	19.96	6	Do.
549	Petrosawodsk, Russia	61 47	34 23	164	23.27	12	Do.
550	Wytegra, Russia	61 0	36 27	131	26.13	6	Do.
551	St. Petersburg, Russia	59 56	30 16	33	18.52	57	Do.
552	Reval, Russia	59 26	24 45	0	19.71	30	Do.
553	Dorpat, Russia	58 23	24 30	33	18.87	5	Do.
554	Reo, Russia	58 19	22 30	33	31.44	4	Do.
555	Riga, Russia	56 57	24 6	33	20.00	31	Do.
556	Orimattila, Russia	60 48	25 44	(?)	27.33	18	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

EUROPE AND THE ADJACENT ISLANDS.

No.	Station.	Lat. N.	Long. W.	Altitude.	Rain.	Years Obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
557	Abo, Russia	60 27	22 17	66	23.79	48	Wild Regen-verhältn.
558	Helsingfors, Russia	60 10	24 57	66	22.24	38	Do.
559	Wilna, Russia	54 41	25 18	394	22.18	11	Do.
560	Pinsk, Russia	52 7	26 6	459	23.48	11	Do.
561	Warschau, Russia	52 13	21 1	394	22.39	72	Do.
562	Radom, Russia	51 24	20 38	558	27.02	15	Do.
563	Kostroma, Russia	57 47	40 55	361	20.14	12	Do.
564	Orenburg, Russia	51 46	55 7	361	15.56	32	Do.
565	Kasan, Russia	55 47	49 8	262	15.26	20	Do.
566	Moskwa, Russia	55 46	37 40	492	21.11	28	Do.
567	Kursk, Russia	51 45	36 8	689	16.96	18	Do.
568	Kiew, Russia	50 26	30 31	591	20.79	29	Do.
569	Kischinew, Russia	46 59	28 51	295	18.45	28	Do.
570	Nikolaow, Russia	46 58	31 58	66	14.39	25	Do.
571	Odessa, Russia	46 29	30 44	230	15.83	36	Do.
572	Kertsch, Russia	45 21	36 29	33	15.11	8	Do.
573	Ssimpheropol, Russia	44 57	34 6	853	16.51	22	Do.
574	Ssewastopol, Russia	44 37	33 31	131	15.15	33	Do.
575	Lugan, Russia	48 35	39 20	197	14.70	45	Do.
576	Astrachan, Russia	46 21	48 2	66	6.13	35	Do.
577	Stawropol, Russia	45 3	41 59	1903	28.23	16	Do.
578	Alaghir, Russia	43 2	74 15	2067	37.35	10	Do.
579	Wladikawkas, Russia	43 2	44 41	2231	34.19	11	Do.
580	Noworossijsk, Russia	44 43	37 46	0	33.42	10	Do.
581	Ssotschi, Russia	43 34	39 42	131	81.44	12	Do.
582	Redut-Kale, Russia	42 16	41 36	33	63.22	6	Do.
583	Kutaiss, Russia	42 16	42 42	459	55.77	14	Do.
584	Poti, Russia	42 9	41 37	0	65.68	13	Do.
585	Tifliss, Russia	41 43	44 47	1411	19.11	38	Do.
586	Alexandropol, Russia	40 48	43 49	4823	14.99	20	Do.
587	Baku, Russia	40 22	49 50	0	9.97	35	Do.
588	Sandwick, Orkney	59 5	3 19W	78	37.23	24	Alexander Buchan.
589	Dunrobin, Scotland	57 59	3 56	14	30.08	24	Do.
590	Portree, Scotland	57 24	6 13	165	88.36	22	Do.
591	Tillydesk, Scotland	57 23	2 5	349	33.53	22	Do.
592	Loch Dhu, Scotland	56 12	4 32	325	83.57	23	Do.
593	Dundee, Scotland	56 28	2 56	167	30.26	18	Do.
594	Dumfries, Scotland	55 2	3 37	159	40.10	24	Do.
595	Seathwaite, England	54 30	3 11	422	143.21	24	Do.
596	Northshields, England	55 0	1 27	124	27.29	24	Do.
597	Macclesfield, England	53 15	2 7	449	37.69	24	Do.
598	York, England	53 57	1 5	60	26.68	24	Do.
599	Beddgelert, Wales	53 0	4 10	264	116.90	20	Do.
600	Festiniog, Wales	52 57	3 54	600	74.56	8	Do.
601	Birmingham, England	52 30	1 54	340	32.37	24	Do.
602	Treherbert, Wales	51 40	3 30	634	89.10	14	Do.
603	Gloucester, England	51 50	2 8	50	27.72	24	Do.
604	Clifton, England	51 27	2 37	192	35.80	24	Do.
605	Newbury, England	51 23	1 18W	335	30.76	24	Do.
606	Hastings, England	50 52	0 32E	77	29.01	24	Do.
607	Southampton, England	50 55	1 24W	75	33.14	24	Do.
608	Penzance, England	50 7	5 33	90	44.66	24	Do.
609	Bellarena, Ireland	55 4	6 56	12	38.25	18	Do.
610	Letterkenny, Ireland	54 57	7 44	108	54.28	12	Do.
611	Belfast, Ireland	54 36	5 56	68	34.73	24	Do.
612	Armagh, Ireland	54 21	6 39	208	31.95	23	Do.
613	Drumkeeran, Ireland	54 9	8 8	1100	52.98	5	Do.
614	Westport, Ireland	53 49	9 35	100	53.28	9	Do.
615	Carlow, Ireland	52 51	6 53	291	36.60	18	Do.
616	Kenmare, Ireland	51 54	9 32	74	69.40	7	Do.
617	Valencia, Ireland	51 54	10 18	11	58.25	23	Do.
618	Cork, Ireland	51 34	8 26	70	36.35	24	Do.
619	Amsterdam, Holland	52 22	4 55E	.....	26.24	6	Dove Beiträge.
620	Utrecht, Holland	52 5	5 7	43	30.39	7	Do.
621	Brussels, Belgium	50 51	4 22	187	28.04	30	Quetelet Met. de Belgium.
622	Liege, Belgium	50 38	5 35	.....	29.63	17	Do.
623	Lille, France	50 38	3 3	.....	22.24	.....	Delesse Bulletin Geography.
624	Rouen, France	49 27	1 4	39	25.59	.....	Do.
625	Compiegne, France	49 24	2 39	.....	15.75	.....	Do.
626	Verdun, France	49 9	5 21	.....	29.13	.....	Do.
627	Paris, France	48 50	2 20	.....	20.08	.....	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

EUROPE AND THE ADJACENT ISLANDS.

No.	Station.	Lat. N.	Long. W.	Altitude.	Rain.	Years. Obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
628	Brest, France	48 24	4 29W	210	28.35	.....	Delesse Bulletin Geography.
629	Le Mans, France	48 0	0 13E	285	28.74	.....	Do.
630	Blois, France	47 36	1 19	.....	27.56	.....	Do.
631	Nantes, France	47 13	1 33W	134	25.59	.....	Do.
632	Bourges, France	47 10	2 26E	510	25.59	.....	Do.
633	Dole, France	47 6	5 29	.....	29.92	.....	Do.
634	Le Blanc, France	46 41	1 3	.....	27.95	.....	Do.
635	Macon, France	46 19	4 49	.....	33.46	.....	Do.
636	La Rochelle, France	46 10	1 9W	.....	25.98	.....	Do.
637	Vichy, France	46 7	3 26E	.....	18.11	.....	Do.
638	Limoges, France	45 51	1 14	.....	36.61	.....	Do.
639	Clermont Ferrand, France	45 46	3 5	1273	20.08	.....	Do.
640	Chamberry, France	45 34	5 53	.....	64.96	.....	Do.
641	Aurillac, France	44 55	2 25	.....	44.49	.....	Do.
642	Rodez, France	44 21	2 34	2050	40.16	.....	Do.
643	Avignon, France	43 57	4 48	65	22.44	.....	Do.
644	Montpellier, France	43 35	3 53	118	29.13	.....	Do.
645	Toulouse, France	43 35	1 26	636	23.62	.....	Do.
646	Bayonne, France	43 30	1 30W	.....	56.30	.....	Do.
647	Marseilles, France	43 18	5 23E	246	20.08	.....	Do.
648	Pau, France	43 18	0 22W	.....	33.07	.....	Do.
649	Perpignan, France	42 42	2 53E	105	23.23	.....	Do.
650	Königsberg, Germany	54 43	20 30	75	23.89	23	Wild Regen-verhältn.
651	Danzig, Germany	54 21	18 40	72	18.73	16	Do.
652	Lubeck, Germany	53 52	10 42	66	21.91	30	Do.
653	Altona, Germany	53 31	9 57	105	25.65	14	Do.
654	Emoden, Germany	53 22	7 12	33	28.14	18	Do.
655	Bremen, Germany	53 5	8 48	49	27.92	37	Do.
656	Berlin, Germany	52 30	13 24	157	23.52	23	Do.
657	Norderney, Germany	53 42	7 7	.....	36.61	11	Do.
658	Posen, Germany	52 25	16 55	269	19.84	23	Do.
659	Hanover, Germany	52 22	9 44	190	22.61	16	Do.
660	Dresden, Germany	51 3	13 44	423	21.36	28	Do.
661	Leipzig, Germany	51 20	12 21	390	22.67	20	Do.
662	Oberwiesenthal, Germany	50 25	12 58	3,041	38.43	18	Do.
663	Köln, Germany	50 55	6 55	184	23.48	23	Do.
664	Stuttgart, Germany	48 46	9 10	879	24.07	45	Do.
665	Karlsruhe, Germany	49 1	8 25	404	28.56	54	Do.
666	Metz, Germany	49 7	6 10	594	25.52	32	Do.
667	Issny, Germany	47 47	10 2	2,365	55.10	32	Do.
668	Prag, Austria	50 5	14 25	663	18.46	50	Do.
669	Krakau, Austria	50 4	19 57	722	24.80	29	Do.
670	Lemberg, Austria	49 50	24 2	978	26.93	45	Do.
671	Brünn, Austria	49 11	16 36	761	19.88	31	Do.
672	Duschlberg, Austria	48 48	13 43	2,959	47.75	11	Do.
673	Wien, Austria	48 14	16 22	656	23.42	34	Do.
674	Salsburg, Austria	47 48	12 59	1,37[illegible]	45.59	30	Do.
675	Budapest, Austria	47 30	19 2	502	20.75	28	Do.
676	Szegedin, Austria	46 15	20 9	295	20.28	20	Do.
677	Agram, Austria	45 50	15 58	515	35.28	20	Do.
678	Hermannstadt, Austria	45 47	24 9	1,345	25.94	28	Do.
679	Triest, Austria	45 38	13 46	.....	43.86	38	Do.
680	Ruksberg, Austria	45 34	22 30	1,247	41.46	12	Do.
681	Bukarest, Austria	44 25	26 5	289	21.38	6	Do.
682	Angra, Azores	38 38	27 15W	.....	42.17	6	Hann's Zeit., v. 6.
683	St. Michael, Azores	37 45	25 15	.....	31.40	10	Do.
684	Oporto, Portugal	41 9	8 36	279	59.41	10	Port. Met. Obs.
685	Granada, Portugal	40 33	7 16	3,409	39.33	10	Do.
686	Coimbra, Portugal	40 13	8 25	.....	33.62	10	Do.
687	Mafra, Portugal	38 55	9 20	746	44.10	10	Do.
688	Lisbon, Portugal	38 43	9 10	312	27.20	10	Do.
689	Serra da Estrella	40 33	7 20	4,728	137.8	5	Symons's Met. Mag.
690	Oviedo, Spain	43 22	5 50	738	36.73	14	Spanish Met. Obs.
691	Vergara, Spain	43 20	2 25	.....	52.32	6	Do.
692	Bilbao, Spain	43 14	2 47	52	48.42	13	Do.
693	Santiago, Spain	42 52	8 28	863	67.52	14	Do.
694	Soria, Spain	41 43	2 26	3,504	24.09	14	Do.
695	Valladolid, Spain	41 40	4 40	2,270	11.85	14	Do.
696	Barcelona, Spain	41 23	2 9 E	138	22.80	14	Do.
697	Salamanca, Spain	41 13	5 43W	2,671	8.11	12	Do.
698	Madrid, Spain	40 25	3 42	2,149	14.76	14	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

EUROPE AND THE ADJACENT ISLANDS.

No.	Station.	Lat.	Long.	Altitude.	Rain.	Years obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
699	Palma, Majorca	39 40 N	2 40 E	.....	17.05	14	Spanish Met. Obs.
700	Albacete, Spain	39 1	1 53W	2,251	12.91	14	Do.
701	San Fernando, Spain	36 28	6 13	95	31.61	14	Do.
702	Gibraltar, Spain	36 7	5 20	49	34.49	.....	Dove Verhandlungen.
703	Schaffhausen, Switzerland	47 42	8 37 E	1,276	39.96	12	Swiss Met. Obs.
704	Kreuzlingen, Switzerland	47 39	9 11	1,404	50.98	16	Do.
705	Trogen, Switzerland	47 25	9 28	2,874	55.67	20	Do.
706	St. Gallen, Switzerland	47 25	9 22	2,185	52.71	17	Do.
707	Altstatten, Switzerland	47 23	9 33	1,542	51.22	20	Do.
708	Zurich, Switzerland	47 23	8 33	1,542	47.01	20	Do.
709	Einsiedeln, Switzerland	47 8	8 45	2,986	64.68	23	Do.
710	Affaltern, Switzerland	47 6	7 45	2,608	49.05	20	Do.
711	Sargans, Switzerland	47 3	9 26	1,643	53.38	15	Do.
712	Glazus, Switzerland	47 3	9 5	1,545	59.96	12	Do.
713	Rigi-kulm, Switzerland	47 3	8 30	5,853	59.18	13	Do.
714	Luzern, Switzerland	47 2	8 17	1,490	48.05	13	Do.
715	Gersau, Switzerland	46 59	8 31	1,509	63.38	14	Do.
716	Neuchatel, Switzerland	46 58	6 53	1,601	38.43	20	Do.
717	Bern, Switzerland	46 57	7 26	1,880	39.61	20	Do.
718	Altdorf, Switzerland	46 53	8 39	1,588	52.52	20	Do.
719	Chur, Switzerland	46 50	9 30	1,978	33.42	15	Do.
720	Engelberg, Switzerland	46 49	8 25	3,360	68.35	17	Do.
721	St. Croix, Switzerland	46 49	6 30	3,593	52.40	12	Do.
722	Interlaken, Switzerland	46 41	7 52	1,831	61.30	14	Do.
723	Platta, Switzerland	46 39	8 51	4,524	51.81	16	Do.
724	Vuardens, Switzerland	46 37	7 1	2,707	51.10	17	Do.
725	Splugen, Switzerland	46 31	9 18	4,826	61.73	16	Do.
726	Bernhardin, Switzerland	46 30	9 13	6,791	85.91	9	Do.
727	Lausanne, Switzerland	45 30	6 37	1,690	40.43	10	Do.
728	Montreux, Switzerland	46 27	6 55	1,263	54.49	14	Do.
729	Sils Maria, Switzerland	46 26	9 46	5,938	38.50	20	Do.
730	Castasegna, Switzerland	46 20	9 31	2,297	58.07	20	Do.
731	Bellinzona, Switzerland	46 13	8 58	751	66.81	15	Do.
732	Geneva, Switzerland	46 12	6 9	1,339	32.13	50	Do.
733	Lugano, Switzerland	46 0	8 57	902	63.80	20	Do.
734	Belluno, Italy	46 8	12 14	1,358	57.25	7	Italiano Ann. Met.
735	Udine, Italy	46 4	13 16	381	60.99	6	Do.
736	Vicenza, Italy	45 33	11 34	184	45.63	12	Do.
737	Venice, Italy	45 26	12 20	69	39.72	12	Do.
738	Milan, Italy	45 28	9 11	482	39.37	17	Do.
739	Padua, Italy	45 24	11 50	98	33.90	11	Do.
740	Turin, Italy	45 4	7 40	902	32.52	17	Do.
741	Alessandria, Italy	44 55	8 39	318	26.30	17	Do.
742	Genoa, Italy	44 25	8 56	177	51.46	17	Do.
743	Bologna, Italy	44 30	11 23	279	24.73	17	Do.
744	Porto Maurizio, Italy	43 53	7 59	207	37.21	7	Do.
745	Florence, Italy	43 46	11 15	249	36.10	17	Do.
746	Urbino, Italy	43 43	12 37	1,480	40.12	17	Do.
747	Ancona, Italy	43 37	13 33	98	28.62	17	Do.
748	Leghorn, Italy	43 33	10 18	79	34.17	17	Do.
749	Rome, Italy	41 54	12 29	164	30.00	17	Do.
750	Foggia, Italy	41 27	15 29	285	18.23	6	Do.
751	Naples, Italy	40 50	14 14	489	32.48	17	Do.
752	Potenza, Italy	40 41	15 52	2,717	24.92	5	Do.
753	Lecce, Italy	40 21	18 10	236	21.34	7	Do.
754	Cosenza, Italy	39 18	16 15	840	47.32	10	Do.
755	Cagliari, Sardinia	39 13	19 7	115	16.57	5	Do.
756	Palermo, Italy	38 7	13 19	236	23.46	17	Do.
757	Cattanisseta, Italy	37 27	14 4	1,870	17.36	7	Do.
758	Syracuse, Italy	37 3	15 17	72	18.62	12	Do.
759	Gospic, Austria	44 33	15 20	1,804	57.76	3	Hann's Zeit., 9.
760	Lesina, Austria	43 11	16 27	30	31.18	12	Do.
761	Ragusa, Austria	42 38	18 7	49	65.71	13	Do.
762	Curzola, Austria	42 55	16 46	59	37.56	11	Do.
763	Durazzo, Turkey	41 21	29 28	23	43.62	5	Do.
764	Constantinople, Turkey	41 0	8 59	230	28.23	38	Do.
765	Valona, Greece	40 27	19 27	105	42.20	14	Do.
766	Janina, Greece	39 47	20 59	1,572	49.56	4	Do.
767	Corfu, Greece	39 40	19 45	72	46.50	22	Do.
768	Athens, Greece	37 58	23 44	361	15.04	12	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

ASIA AND THE ADJACENT ISLANDS.

No.	Station.	Lat.	Long.	Altitude.	Rain.	Years obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
769	Sagastyr	73 22 N	126 35 E	?	3.40	2	Wild Regen-verhältn.
770	Tolstoj-Noss	70 10	82 50	33	11.76	1	Do.
771	Obdorsk	66 31	66 35	66	8.57	2	Do.
772	Turuchansk	65 55	87 38	66	17.98	5	Do.
773	Beresow	63 56	65 4	66	18.40	4	Do.
774	Jakutsk	62 1	129 42	525	13.71	9	Do.
775	Olekminsk	60 22	120 40	656	10.89	2	Do.
776	Preobrashenskoe	60 0	107 56	1,050	11.18	1	Do.
777	Bogoslowsk	59 45	60 1	623	16.19	45	Do.
778	Ochotsk	59 21	143 17	33	7.53	6	Do.
779	Enisseisk	58 27	92 6	262	15.46	12	Do.
780	Blagodat	58 17	59 47	1,247	11.65	6	Do.
781	Tobolsk	58 12	68 14	164	18.64	10	Do.
782	Tara	56 54	74 17	230	14.77	4	Do.
783	Tomsk	56 30	84 58	230	15.11	8	Do.
784	Ajan	56 28	138 17	33	44.01	6	Do.
785	Dolmatow	56 13	63 0	394	12.60	21	Do.
786	Kainsk	55 27	78 20	361	9.83	2	Do.
787	Omsk	54 58	73 20	262	12.69	3	Do.
788	Ssalair	54 15	85 47	1,115	13.98	7	Do.
789	Wercholensk	54 8	105 30	?	12.62	2	Do.
790	Barnaul	53 20	83 47	459	10.11	45	Do.
791	Nikolaewsk	53 8	140 45	66	16.28	20	Do.
792	Petropawlowsk	53 0	158 48	33	48.86	7	Do.
793	Irkutsk	52 17	104 22	1,509	16.47	9	Do.
794	Werchne-Udinsk	51 50	107 41	1,739	7.55	2	Do.
795	Post Alexandrowskij	51 28	140 50	49	21.18	5	Do.
796	Nertschinsk	51 19	119 37	2,165	16.21	42	Do.
797	Duë	50 50	142 9	361	18.51	4	Do.
798	Ssemipalatinsk	50 24	80 13	591	7.33	7	Do.
799	Kjachta	50 20	106 35	2,526	9.96	5	Do.
800	Karkoraly	49 24	75 31	?	16.06	2	Do.
801	Irgis	48 37	61 16	361	6.89	20	Do.
802	Chabarowka	48 28	135 7	1,357	22.04	4	Do.
803	Urga	47 55	106 51	3,773	7.94	5	Do.
804	Korssakowskij	46 39	142 48	66	22.72	3	Do.
805	Raimsk	46 4	61 47	164	7.28	7	Do.
806	Kasalinsk	45 46	62 7	197	4.06	11	Do.
807	Perowskij	44 51	65 27	394	4.32	9	Do.
808	Alexandrowsk	44 27	50 8	—33	4.96	19	Do.
809	St. Olga	43 44	135 20	33	20.16	6	Do.
810	Wernyj	43 16	76 53	2,395	22.28	4	Do.
811	Wladiwostok	43 9	132 0	98	13.23	9	Do.
812	Nukuss	42 27	59 37	230	3.33	7	Do.
813	Taschkent	41 20	69 16	1,493	12.90	11	Do.
814	Osch	40 33	72 47	3,937	18.84	2	Do.
815	Kokand	40 32	70 57	1,280	5.99	2	Do.
816	Krasnowodsk	40 0	52 59	—66	14.70	4	Do.
817	Pekin	39 57	116 29	131	24.56	33	Do.
818	Ssamarkand	39 39	66 57	2,379	12.91	3	Do.
819	Lenkoran	38 46	48 51	—66	47.21	18	Do.
820	Aschur-Ade	36 54	53 57	—66	17.17	19	Do.
821	Smyrna	38 26	27 10	.....	25.63	20	Do.
822	Ooromiah	37 28	45 8	7,334	21.51	1	Am. Jo. Sc., 20.
823	Teheran	35 41	51 25	3,714	11.20	1	Met. Annalen, 1884.
824	Larnaka	34 55	33 39	25	12.80	4	Sc. Met. Soc., 5.
825	Beirut	33 54	35 29	.....	37.82	8	Austrian Jahrbuch.
826	Bagdad	33 21	44 22	.....	6.00	.....	Guyot's Ph. Geog., 124.
827	Jerusalem	31 46	35 13	2,500	22.17	15	Sc. Met. Soc.
828	Bushire	28 59	50 49	25	14.50	8	Meteorology of India.
829	Aden	12 45	45 3	94	2.84	4	Do.
830	Yarkand	38 25	77 16	4,015	0.52	½	Do.
831	Leh, Kashmir	34 10	77 42	1,1503	2.59	10	Do.
832	Peshawar	34 2	71 37	1,110	13.49	27	Do.
833	Rawal Pindi	33 38	73 5	1,652	32.33	27	Do.
834	Bannu	33 1	70 40	1,276	12.86	23	Do.
835	Dera Ismail Khan	32 0	71 5	572	8.32	23	Do.
836	Amri Star	31 40	74 50	756	25.92	25	Do.
837	Lahore	31 34	74 20	732	21.54	27	Do.
838	Jhang	31 16	72 19	570	10.81	23	Do.
839	Simla	31 6	77 12	7,030	70.50	23	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

ASIA AND THE ADJACENT ISLANDS.

No.	Station.	Lat.	Long.	Altitude.	Rain.	Years obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
840	Ferozepore	30 56 N	74 40 E	646	22.00	35	Meteorology of India.
841	Chakrata	30 40	77 55	7,052	61.46	17	Do.
842	Quetta	30 11	67 3	5,501	9.88	8	Do.
843	Mooltan	30 10	71 33	420	7.11	24	Do.
844	Muzaffargarh	30 4	71 16	388	6.04	25	Do.
845	Roorkee	29 52	77 56	886	42.48	31	Do.
846	Hissar	29 3	75 47	689	15.77	34	Do.
847	Rudarpore	29 0	79 32	718	44.56	26	Do.
848	Delhi	28 40	77 16	718	27.51	36	Do.
849	Jacobabad	28 24	68 18	185	4.50	25	Do.
850	Katmandu	27 42	85 12	4,388	56.76	32	Do.
851	Dibrugarh	27 34	95 2	405	111.83	23	Do.
852	Rohri	27 38	68 55	190	5.40	24	Do.
853	Darjeeling	27 3	88 18	7,421	121.20	26	Do.
854	Sibsagar	26 59	94 40	333	93.63	30	Do.
855	Jeypore	26 55	75 50	1,431	23.97	18	Do.
856	Baxa	26 47	89 36	2,076	215.23	16	Do.
857	Motiharee	26 38	85 0	217	47.86	27	Do.
858	Jalpaiguri	26 32	88 50	270	128.06	16	Do.
859	Sewan	26 31	67 48	119	6.93	20	Do.
860	Kissengunge	26 6	87 53	.....	72.46	14	Do.
861	Deoli	25 53	75 30	1,122	33.95	24	Do.
862	Muddelipoora	25 52	86 50	.....	52.57	15	Do.
863	Purneah	25 50	87 34	125	63.39	15	Do.
864	Rungpore	25 44	89 25	120	84.55	27	Do.
865	Hyderabad	25 25	68 27	134	8.04	21	Do.
866	Umarkot	25 20	69 42	100	11.09	19	Do.
867	Bhagalpur	25 18	87 16	159	46.97	31	Do.
868	Cherra Poonje	25 14	91 40	4,125	474.54	26	Do.
869	Erimpura	25 13	73 6	1,142	15.35	18	Do.
870	Maldah	24 58	88 19	100	53.24	29	Do.
871	Bogra	24 49	89 26	77	76.03	24	Do.
872	Silchar	24 49	92 50	104	119.16	28	Do.
873	Mymensingh	24 48	90 30	60	94.06	25	Do.
874	Kurrachee	24 47	67 4	49	7.38	29	Do.
875	Tatta	24 46	68 0	39	8.16	17	Do.
876	Beauleah	24 26	88 38	35	58.98	29	Do.
877	Nya Doomka	24 24	87 23	120	57.10	15	Do.
878	Atia	24 14	90 0	35	66.30	15	Do.
879	Palumpur	24 8	72 30	700	32.57	16	Do.
880	Puhna	24 4	89 19	25	65.79	23	Do.
881	Dacca	23 43	90 27	22	73.34	36	Do.
882	Furreeapore	23 36	89 51	20	70.48	19	Do.
883	Comillah	23 33	91 20	60	93.57	28	Do.
884	Ranchee	23 28	85 22	2,169	49.44	29	Do.
885	Jessore	23 9	89 13	33	67.96	28	Do.
886	Noakholly	22 52	91 14	50	112.14	28	Do.
887	Burrisal	22 44	90 20	18	80.14	20	Do.
888	Calcutta	22 33	88 21	18	65.54	56	Do.
889	Rangamatia Hill	22 32	92 17	142	96.50	17	Do.
890	Chybassa	22 26	85 48	746	56.30	16	Do.
891	Chittagong	22 21	91 50	86	105.00	29	Do.
892	Rajkot	22 17	70 52	429	27.73	22	Do.
893	Sambalpur	21 30	84 5	451	61.96	24	Do.
894	Surat	21 13	72 46	36	41.77	20	Do.
895	Cuttack	20 29	85 54	80	57.48	26	Do.
896	Akgah	20 28	92 57	20	197.30	28	Do.
897	Pooree	19 48	85 58	15	55.70	29	Do.
898	Igatpuri	19 47	73 35	1,922	125.90	19	Do.
899	Tanna	19 23	72 49	24	97.80	22	Do.
900	Ganjam	19 22	85 10	40	40.31	22	Do.
901	Matheran	19 0	73 12	2,200	208.13	15	Do.
902	Prome	18 58	95 20	128	51.20	16	Do.
903	Toungoo	18 57	96 24	181	77.96	16	Do.
904	Colaba	18 54	72 49	37	74.01	54	Do.
905	Byculla	18 50	72 49	.....	81.80	20	Do.
906	Lonauli	18 48	73 26	2,037	164.62	12	Do.
907	Poona	18 28	74 10	1,849	28.43	42	Do.
908	Sandoway	18 10	94 5	50	213.92	24	Do.
909	Myanaung	18 10	95 28	74	52.96	11	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

ASIA AND THE ADJACENT ISLANDS.

No.	Station.	Lat.	Long.	Altitude.	Rain.	Years obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
910	Shwegyin	18 6 N	96 46 E	128	142.11	17	Meterology of India.
911	Mahableshwar	17 56	73 38	4,540	261.26	30	Do.
912	Henzada	17 45	95 32	44	79.96	15	Do.
913	Ratangira	17 6	73 23	110	104.21	23	Do.
914	Bijapur	16 52	75 45	1,999	23.98	20	Do.
915	Bassein	16 47	94 50	35	103.35	16	Do.
916	Rangoun	16 46	96 12	40	98.89	16	Do.
917	Moulmein	16 29	97 40	94	188.90	36	Do.
918	Baura	16 29	74 0	2,800	251.54	13	Do.
919	Kaladgi	16 18	75 40	1,744	21.68	17	Do.
920	Raichur	16 16	77 27	1,325	23.95	10	Do.
921	Gokak	16 11	74 52	2,500	22.06	20	Do.
922	Lingsugur	16 11	76 24	1,300	22.79	10	Do.
923	Belgaum	15 52	74 42	2,550	48.97	33	Do.
924	Goa	15 21	73 56	23	102.50	24	Do.
925	Mandagi	15 12	75 54	1,950	18.21	12	Do.
926	Bellary	15 9	76 57	1,455	17.74	32	Do.
927	Gooty	15 7	77 44	1,168	21.73	29	Do.
928	Dharmavaram	14 30	77 55	.....	21.38	16	Do.
929	Tavoy	14 7	98 18	20	195.78	28	Do.
930	Mangalore	12 52	74 54	52	131.84	29	Do.
931	Mercara	12 26	75 48	3,694	127.82	22	Do.
932	Mysore	12 20	76 37	2,513	28.43	48	Do.
933	Mergui	12 11	98 38	96	158.81	21	Do.
934	Manantoddy	11 48	76 0	2,685	97.56	18	Do.
935	Calicut	11 15	75 32	50	115.06	24	Do.
936	Palghat	10 46	76 45	800	73.70	23	Do.
937	Cochin	9 58	76 17	11	115.57	29	Do.
938	Madura	9 55	78 10	448	34.85	25	Do.
939	Mannar	9 0	80 6	.....	40.19	15	Do.
940	Trincomalle	8 34	81 10	175	61.98	15	Do.
941	Anuradhapura	8 10	80 22	302	54.82	15	Do.
942	Batticaloa	7 39	81 46	21	59.12	15	Do.
943	Kandy	7 18	80 40	1,696	84.09	16	Do.
944	Colombo	6 56	79 52	40	87.32	16	Do.
945	Newera Eliya	6 46	80 47	6,240	98.87	15	Do.
946	Galle	6 1	80 14	48	89.96	16	Do.
947	Singapore	1 42	103 50	.....	89.87	17	Do.
948	Shien Sheen	38 17	117 10	.....	21.77	4	Hann's Zeit., 17.
949	Shanghai	31 19	121 16	.....	43.35	.....	Dr. A. Woeikoff.
950	Zikawei	31 13	121 26	.....	42.44	8	Hann's Zeit., 17.
951	Kelung	25 20	121 46	.....	120.08	2	Dr. A. Woeikoff.
952	Canton	23 15	113 16	.....	77.64	.....	Dove Beiträge.
953	Hong-Kong	22 20	114 13	.....	84.45	12	Dr. A. Woeikoff.
954	Macao	22 10	113 32	.....	69.10	14	Dove Beiträge.
955	Hanoi Tonkin	21 2	105 48	.....	70.91	1	Hann's Zeit., 19.
956	Bangkok	11 45	100 30	.....	58.55	10	Hann's Zeit., 15.
957	Saigon	10 47	106 45	.....	82.96	7	Hann's Zeit., 19.
958	Sapporo, Japan	43 4	141 23	60	40.63	4	Meteorology of Japan.
959	Hakodate	41 46	140 44	10	44.45	7	Do.
960	Aomori	40 51	140 45	33	44.76	4	Do.
961	Akita	39 42	140 7	33	66.68	4	Do.
962	Niigata	37 55	139 3	32	70.13	4	Do.
963	Kanazawa	36 33	136 40	95	109.19	4	Do.
964	Tokio	35 41	139 45	69	60.43	10	Do.
965	Sakai	35 33	133 14	8	75.70	4	Do.
966	Gifu	35 27	136 46	49	75.41	4	Do.
967	Numazu	35 6	138 51	33	70.78	4	Do.
968	Kioto	35 1	135 46	162	58.91	4	Do.
969	Hamamatsu	34 42	137 43	90	71.12	4	Do.
970	Osaka	34 41	135 30	44	52.42	4	Do.
971	Wakayama	34 14	135 9	48	55.85	4	Do.
972	Shimonoseki	33 58	130 57	134	68.58	4	Do.
973	Kochi	33 33	133 34	20	92.92	4	Do.
974	Nagasaki	32 44	129 52	189	77.56	6	Do.
975	Miyasaki	31 56	131 26	26	102.08	4	Do.
976	Kagoshima	31 35	130 33	11	82.39	4	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

AFRICA AND THE ADJACENT ISLANDS.

No.	Station.	Lat.	Long.	Altitude.	Rain.	Years obs.	uthority.
		° ′	° ′	*Feet.*	*Inches.*		
977	Funchal, Madeira	32 28 N	16 55 W	82	29.21	16	Hann's Zeit., 6.
978	Teneriffe, Canary Islands	28 12	16 21	1,867	33.30	10	Obs. de Provincias.
979	Las Palmas	27 28	15 28	30	4.72	1	Do.
980	Praia, Cape Verde Island	14 54	23 31	112	12.72	5	Hann's Zeit., 16.
981	Cap de Garde, Algeria	36 58	7 47 E	.....	12.62	4	Met. de France.
982	La Calle	36 54	8 26	36	29.73	5	Do.
983	Philippeville	36 53	6 54	.....	24.00	5	Do.
984	Djidjelli	36 50	5 43	43	32.74	4	Do.
985	Algiers	36 47	3 4	72	26.72	5	Do.
986	Bougie	36 47	5 5	220	31.31	4	Do.
987	Staoueli	36 44	2 55	377	20.02	5	Do.
988	Fort Nationale	36 38	4 12	3,051	36.72	4	Do.
989	Guelma	36 28	7 27	915	20.04	5	Do.
990	Constantine	36 22	6 36	2,165	18.84	4	Do.
991	Tizi Ouzon	36 22	4 3	768	27.06	4	Do.
992	Medeah	36 16	2 45	3,002	25.88	5	Do.
993	Setif	36 11	5 26	3,563	13.11	5	Do.
994	Aumale	36 10	3 41	2,969	15.40	5	Do.
995	Orleansville	36 10	1 21	387	12.14	5	Do.
996	Teniet-el-Had	35 53	2 1	3,750	20.05	5	Do.
997	Cap Falcon	35 46	0 47 W	256	27.24	5	Do.
998	Oran	35 42	0 39	174	15.00	5	Do.
999	Tebessa	35 24	8 6 E	2,890	13.18	4	Do.
1000	Batna	35 22	6 10	3,471	12.35	5	Do.
1001	Bou-Saada	35 10	4 15	2,139	8.09	2	Do.
1002	Nemours	35 6	1 51 W	13	9.95	5	Do.
1003	Sidi-Bel-Abbès	35 2	0 39	1,562	11.76	5	Do.
1004	Tlemcer	34 53	1 18	2,703	18.98	5	Do.
1005	Biskra	34 51	5 40 E	410	2.76	5	Do.
1006	Saida	34 51	0 10	2,845	11.16	5	Do.
1007	Djelfa	34 40	3 8	3,829	9.64	5	Do.
1008	El Aricha	34 16	1 13 W	4,101	7.08	5	Do.
1009	Aflau	34 13	2 3 E	4,429	9.20	5	Do.
1010	Laghouat	33 48	2 51	2,526	5.17	5	Do.
1011	Geryville	33 45	1 10	4,285	7.39	5	Do.
1012	Mogador	31 30	12 4 W	54	9.50	3	Do.
1013	Tunis	36 47	10 11 E	46	12.20	1	Do.
1014	Port Said	31 18	32 18	10	2.06	2	Hann's Zeit., 7.
1015	Alexandria	31 12	29 52	62	8.60	15	Hann's Zeit., 12.
1016	Ismailia	30 38	32 13	25	1.40	2	Hann's Zeit., 7.
1017	Cairo	30 5	31 17	96	1.34	5	Do.
1018	Suez	29 57	32 32	20	1.09	2	Do.
1019	Keneh	26 39	32 45	.....	0.00	.....	Johnston's Africa.
1020	Mourzouk	25 54	14 12	.....	0.00	.....	Gehler's Wörterbuch.
1021	Thebes	25 43	32 35	.....	0.00	.....	Wilkinson's Egypt.
1022	St. Louis, Senegal	16 1	16 30 W	.....	16.06	7	Hann's Zeit., 8.
1023	Goree	14 40	17 31	20	20.95	10	Do.
1024	Kuka	12 42	13 20 E	.....	33.00	.....	Guyot's Ph. Atlas.
1025	Gondar	12 36	37 31	.....	37.38	.....	Berghaus Ph. Atlas.
1026	Gando	12 22	4 34	.....	60.00	.....	Johnston's Africa.
1027	Freetown	8 29	13 9 W	250	125.80	5	Hann's Zeit., 5.
1028	Bahr el Jebel	8 0	30 0 E	.....	70.00	.....	Johnston's Africa.
1029	Lagos	6 12	3 25	.....	74.06	2	Hann's Zeit., 13.
1030	Aburi	5 51	0 9 W	1,542	41.68	.....	Symon's Met. Mag., 20.
1031	Christiansburg	5 36	0 10	66	22.64	9	Journal Met. Soc., 2.
1032	Elmina	5 5	1 20	59	30.79	3	Do.
1033	Cape Palmas	4 22	7 44	.....	82.07	.....	Berghaus Ph. Atlas.
1034	Fernando Po	3 46	8 36 E	98	100.67	4	Journal Met. Soc., 2.
1035	Gaboon	0 25	9 35	287	93.82	5	A. v. Danckelman.
1036	St. Thomas Island	0 20	6 43	16	40.16	.....	Dr. A. Woeikoff.
1037	Victoria Nyanza	0 0	32 0	.....	49.00	.....	Speke's Central Africa.
1038	Mombas	4 0 S	39 35	.....	59.26	.....	Dr. A. Woeikoff.
1039	Bambarre	4 37	27 52	.....	58.00	.....	Johnston's Africa.
1040	Chincoxo	5 9	12 3	39	42.60	2	A. v. Danckelman.
1041	Vivi	5 40	13 49	372	42.48	1	Do.
1042	Ponta da Lenha	5 56	12 45	16	29.09	1	Do.
1043	Zanzibar	6 10	39 11	23	56.17	9	Met. of India.
1044	Ascension	7 55	14 25 W	52	3.30	2	Charts of Met. Data.
1045	St. Paul de Loando	8 49	13 7 E	194	20.83	2	A. v. Danckelman.
1046	Bangweolo	11 15	28 20	.....	47.50	2	Johnston's Africa.
1047	Livingstonia	14 0	34 46	.....	30.00	.....	Hann's Zeit., 16.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

AFRICA AND THE ADJACENT ISLANDS.

No.	Station.	Lat.	Long.	Altitude.	Rain.	Years obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
1048	St. Helena Island	15 57 S	5 41W	1,765	47.77	.....	Mag. and Met. Obs.
1049	Tete	16 10	33 30 E	250	33.55	1	Hann's Zeit., 7.
1050	Tananarivo, Madagascar	19 0	47 6	.....	52.68	4	Symon's Met. Mag., 20.
1051	Port Louis, Mauritius	20 10	57 30	30	52.46	10	Do.
1052	Cluny, Mauritius	20 23	57 34	960	147.56	9	Do.
1053	Omaruru	21 35	16 13	3,500	8.00	1	A. v. Danckelman.
1054	Pretoria	25 45	28 50	4,462	23.62	2	Hann's Zeit., 17.
1055	Motito	27 0	24 37	.....	20.55	2	Do. 7.
1056	Pella	29 4	19 12	1,804	2.20	5	Do. 20.
1057	Ottawa	29 38	31 7	300	38.98	10	Do.
1058	Springbockfontein	29 40	17 53	3,200	8.03	6	Do.
1059	Hopetown	29 40	24 10	3,609	10.75	6	Do.
1060	Merebank	29 55	30 55	30	44.21	9	Do.
1061	Prieska	30 20	21 45	3,297	8.94	6	Do.
1062	Philipstown	30 25	24 23	4,495	10.83	6	Do.
1063	Aliwal, North	30 43	26 43	4,400	24.69	17	Do.
1064	Carnarvon	30 56	22 6	4,052	7.79	6	Do.
1065	Queenstown	31 51	26 51	3,500	20.75	12	Do.
1066	Brakfontein	31 52	23 0	4,100	9.65	10	Do.
1067	Frasersburg	31 54	21 31	4,003	6.10	6	Do.
1068	Tarkastad	32 0	26 16	4,298	17.09	6	Do.
1069	Wellwood	32 5	24 45	4,003	12.72	9	Do.
1070	Goliad's Kraal	32 8	24 40	3,494	13.97	20	Do.
1071	Clan William	32 10	18 53	295	8.03	6	Do.
1072	Graaf Reinet	32 16	24 34	2,500	14.53	23	Do.
1073	Camfer's Kraal	32 17	23 3	3,000	8.46	16	Do.
1074	Beaufort, West	32 21	22 37	2,850	9.17	6	Do.
1075	Roodeberg	32 28	23 45	.....	11.10	6	Do.
1076	Somerset, East	32 44	25 35	2,400	17.52	13	Do.
1077	Fort Beaufort	32 46	26 37	1,493	24.60	5	Do.
1078	King Williamstown	32 51	27 22	1,314	25.71	15	Do.
1079	Rietfontein	32 52	24 5	2,264	11.46	16	Do.
1080	Piquetberg	32 53	18 45	771	17.44	5	Do.
1081	Jansenville	32 56	24 41	.....	9.45	6	Do.
1082	Saron	33 11	19 0	590	22.17	6	Do.
1083	Willowmore	33 13	23 30	2,500	7.40	6	Do.
1084	Prince Albert	33 14	22 0	2,100	7.72	6	Do.
1085	Grahamstown	33 20	26 33	1,800	28.78	22	Do.
1086	East London	33 20	27 55	16	27.91	5	Do.
1087	Amalienstein	33 27	21 24	1,493	13.74	16	Do.
1088	Groote Post	33 28	18 24	.....	18.50	18	Do.
1089	Salem	33 30	26 33	492	21.61	5	Do.
1090	Catitzdorp	33 32	21 42	607	7.48	5	Do.
1091	Oudtshoorn	33 36	22 13	1,100	8.54	5	Do.
1092	Worcester	33 40	19 27	787	13.62	17	Do.
1093	Robertson	33 47	19 51	590	10.91	6	Do.
1094	Uitenhage	33 47	25 24	197	15.87	22	Do.
1095	Cape Observatory	33 56	18 29	33	24.80	42	Do.
1096	Port Elizabeth	33 57	25 37	180	22.95	17	Do.
1097	Bishop's Court	33 59	18 27	262	53.54	13	Do.
1098	Wynberg	34 0	18 2	250	42.72	17	Do.
1099	Somerset, West	34 5	18 52	98	24.17	8	Do.
1100	Mossel Bay	34 11	22 9	105	15.98	8	Do.
1101	Simonstown	34 12	18 26	16	28.27	10	Do.
1102	Bredasdorp	34 33	20 2	246	18.74	8	Do.

AUSTRALIA AND THE ADJACENT ISLANDS.

1103	Palmerston	12 26	130 52	70	63.21	13	Todd's Met. Obs.
1104	Southport	12 44	131 0	.....	62.73	9	Do.
1105	Yam Creek	13 29	131 35	.....	49.53	10	Do.
1106	Pine Creek	13 52	131 56	.....	44.87	7	Do.
1107	River Katherine	14 23	132 17	.....	43.25	10	Do.
1108	Daly Waters	16 17	133 29	750	31.19	10	Do.
1109	Powell's Creek	18 7	133 55	.....	19.58	9	Do.
1110	Tennant's Creek	19 34	134 7	.....	18.18	9	Do.
1111	Barrows' Creek	21 30	133 44	.....	15.45	9	Do.
1112	Alice Springs	23 38	133 37	2,100	12.59	9	Do.
1113	Charlotte Waters	25 50	134 57	.....	6.42	9	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

AUSTRALIA AND THE ADJACENT ISLANDS.

No.	Station.	Lat.	Long.	Altitude.	Rain.	Years obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
1114	Peake	28 4 S	135 50 E	.....	5.64	9	Todd's Met. Obs.
1115	Strangways Springs	29 11	136 33	.....	5.24	9	Do.
1116	Blinman	31 7	138 42	.....	14.37	17	Do.
1117	Beltana	30 58	138 27	.....	9.11	9	Do.
1118	Mattawarrungalla	31 58	138 50	.....	11.45	15	Do.
1119	Kanyaka	32 2	138 5	.....	12.40	16	Do.
1120	Outalpa	32 11	140 12	.....	10.59	15	Do.
1121	Port Augusta	32 29	137 45	10	8.81	23	Do.
1122	Mount Remarkable	32 44	138 15	.....	16.27	10	Do.
1123	Melrose	32 46	138 8	.....	24.31	19	Do.
1124	Appila	33 2	138 24	.....	13.36	9	Do.
1125	Georgetown	33 23	138 21	.....	16.21	9	Do.
1126	Kooringa	33 42	138 59	.....	17.39	24	Do.
1127	Bungaree	33 44	138 31	.....	21.15	23	Do.
1128	Clare	33 50	138 37	.....	24.18	21	Do.
1129	Wallaroo	32 53	137 40	.....	13.40	19	Do.
1130	Auburn	34 2	138 38	.....	25.08	18	Do.
1131	Kapunda	34 21	138 55	.....	19.76	22	Do.
1132	Tanunda	34 30	138 56	.....	21.14	15	Do.
1133	Yarroo	34 7	138 4	.....	16.56	13	Do.
1134	Gawler	34 35	138 45	.....	18.85	22	Do.
1135	Adelaide	34 57	138 35	.....	20.25	26	Do.
1136	Mount Lofty	35 0	138 43	.....	42.25	25	Do.
1137	Clarendon	35 6	138 36	.....	29.57	12	Do.
1138	Willunga	35 16	138 31	.....	26.08	21	Do.
1139	Normanville	35 25	138 18	.....	19.92	16	Do.
1140	Cape Jervis	35 35	138 4	.....	15.58	8	Do.
1141	Gumeracha	34 47	138 55	.....	32.31	14	Do.
1142	Charleston	34 58	138 51	.....	32.65	18	Do.
1143	Kanmantoo	35 3	139 0	.....	16.60	9	Do.
1144	Mount Barker	35 4	138 46	.....	29.12	22	Do.
1145	Strathalbyn	35 16	138 55	.....	18.51	22	Do.
1146	Woodburn	35 20	139 3	.....	15.72	20	Do.
1147	Paringa	34 10	140 44	.....	10.37	10	Do.
1148	Blanchetown	34 20	139 37	.....	11.97	15	Do.
1149	Meningie	35 41	139 19	.....	18.90	19	Do.
1150	Moonta	34 3	137 37	.....	13.72	11	Do.
1151	Edithburgh	35 3	137 47	.....	17.22	8	Do.
1152	Port Lincoln	34 42	135 55	.....	19.37	17	Do.
1153	Cape Borda	35 45	136 35	.....	23.54	14	Do.
1154	American River	35 44	137 46	.....	20.00	17	Do.
1155	Goolwa	35 29	138 47	.....	16.85	19	Do.
1156	Kingston	36 47	139 53	.....	21.27	8	Do.
1157	Robe	37 10	139 45	.....	24.24	22	Do.
1158	Cape Northumberland	38 5	140 40	117	28.44	16	Do.
1159	Naracoorte	36 56	139 47	.....	21.28	15	Do.
1160	Penula	37 21	140 50	.....	27.72	22	Do.
1161	Mount Gambier	37 50	140 50	130	31.28	22	Do.
1162	Geraldton	28 47	114 36	5	17.13	2	Fraser's Met. Obs.
1163	New Castle	31 38	116 34	.....	12.28	1	Do.
1164	Northam	31 40	116 45	.....	8.31	1	Do.
1165	York	31 53	116 47	580	15.53	2	Do.
1166	Guildford	31 55	115 56	.....	38.25	2	Do.
1167	Perth	31 57	115 52	.....	32.58	4	Do.
1168	Rottnest Island	32 0	115 33	24	25.31	1	Do.
1169	Freemantle	32 2	115 42	.....	26.45	2	Do.
1170	Pinjarra	32 34	115 52	.....	35.55	2	Do.
1171	Banbury	33 18	115 32	.....	41.90	2	Do.
1172	Vasse	33 32	115 28	.....	27.75	2	Do.
1173	Albany	35 0	117 53	.....	35.55	2	Do.
1174	Beechal	27 0	144 0	.....	16.21	10	Russell's Met. Obs.
1175	Norley	27 45	144 3	.....	12.89	10	Do.
1176	Antony	28 22	153 27	.....	58.92	5	Do.
1177	Maryland	28 36	152 5	.....	32.90	19	Do.
1178	Casino	28 50	153 0	.....	38.85	12	Do.
1179	Trigamon	29 0	150 54	.....	25.92	10	Do.
1180	Tenterfield	29 5	152 4	.....	29.71	16	Do.
1181	Strathbogie	29 28	151 32	.....	33.12	13	Do.
1182	Mount Poole	29 35	141 54	.....	8.36	7	Do.
1183	Grafton	29 43	152 56	.....	33.83	16	Do.
1184	Ursino	29 48	143 35	.....	8.91	20	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

AUSTRALIA AND THE ADJACENT ISLANDS.

No.	Station.	Lat.	Long.	Altitude.	Rain.	Years obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
1185	Brewarrina	29 59 S	146 35 E	.....	18.85	14	Russell's Met. Obs.
1186	Goorimpa	30 22	144 1	.....	9.76	11	Do.
1187	Charlton	30 27	146 50	.....	18.42	14	Do.
1188	Tongo	30 28	143 46	.....	9.37	7	Do.
1189	Booroolong	30 33	151 22	.....	34.04	12	Do.
1190	Armidale	30 34	151 46	.....	32.72	22	Do.
1191	Tarella	30 55	143 0	.....	10.80	10	Do.
1192	Momba	30 59	143 28	.....	11.13	13	Do.
1193	Caiga	31 7	148 44	.....	18.79	12	Do.
1194	Billilla	31 10	144 55	.....	9.21	9	Do.
1195	Goonoo	31 20	150 54	.....	23.73	11	Do.
1196	Port Macquarie	31 25	152 54	.....	60.05	29	Do.
1197	Wilcannia	31 31	143 23	.....	10.83	13	Do.
1198	Murrurundi	31 46	150 51	.....	29.67	14	Do.
1199	Mount Gipps	32 0	141 45	.....	8.86	10	Do.
1200	Scone	32 4	150 53	.....	21.41	11	Do.
1201	Weinteriga	32 8	142 46	.....	8.81	9	Do.
1202	Teryawynia	32 20	143 20	.....	9.65	9	Do.
1203	Kinchega	32 30	142 25	.....	8.97	11	Do.
1204	Melrose	32 42	147 0	.....	17.94	14	Do.
1205	Dalwood	32 42	151 20	.....	31.39	23	Do.
1206	Netly Head	32 53	142 20	.....	8.78	8	Do.
1207	Lambton	32 53	151 44	.....	53.48	5	Do.
1208	New Castle	32 55	151 50	.....	46.41	24	Do.
1209	Mulurulu	32 59	143 25	.....	8.34	5	Do.
1210	Cuthero	33 2	142 25	.....	8.78	5	Do.
1211	Kilfera	33 6	144 7	.....	11.71	14	Do.
1212	Orange	33 18	149 9	.....	35.84	16	Do.
1213	Manfred	33 18	143 44	.....	8.75	6	Do.
1214	Tarcoola	33 25	142 37	.....	9.96	8	Do.
1215	Forbes	33 27	148 5	.....	18.06	10	Do.
1216	Cooerwull	33 30	150 7	.....	31.47	17	Do.
1217	Mount Victoria	33 36	150 15	.....	33.84	13	Do.
1218	Windsor	33 36	150 49	.....	32.80	23	Do.
1219	Arumpo	33 44	143 11	.....	8.43	6	Do.
1220	Burtundy	33 44	142 27	.....	9.45	6	Russell's Met. Obs.
1221	Woodford	33 44	150 24	.....	53.56	4	Do.
1222	Parramatta	33 48	151 1	.....	38.95	15	Do.
1223	Sydney	33 51	151 12	.....	49.86	46	Do.
1224	Camden Park	34 5	150 44	.....	32.69	26	Do.
1225	Young	34 18	148 21	.....	26.41	15	Do.
1226	Cordeaux River	34 19	.....	.....	53.37	15	Do.
1227	Wollongong	34 25	150 56	.....	38.79	15	Do.
1228	Mossvale	34 32	150 23	.....	41.50	13	Do.
1229	Goulburn	34 45	149 45	.....	25.35	27	Do.
1230	Ganmain	34 56	147 0	.....	21.31	14	Do.
1231	Wagga	35 8	147 24	.....	22.08	14	Do.
1232	Cape St. George	35 12	150 45	175	53.33	19	Do.
1233	Gungahleen	35 12	149 8	.....	28.00	11	Do.
1234	Wanganella	35 13	144 54	.....	15.48	16	Do.
1235	Burrongong	35 31	146 38	.....	18.30	10	Do.
1236	Lalaltee	35 38	145 49	.....	18.89	11	Do.
1237	Kiandra	35 52	148 32	.....	60.61	14	Do.
1238	Moruya Heads	35 53	150 6	.....	36.35	10	Do.
1239	Mulwala	35 59	146 3	.....	18.87	10	Do.
1240	Bodalla	36 4	149 59	.....	35.84	10	Do.
1241	Albury	36 6	147 0	.....	26.39	23	Do.
1242	Eden	37 0	149 59	.....	36.12	17	Do.
1243	Beechworth	36 24	146 24	1,783	29.29	4	Ellery's Met. Obs.
1244	Sandhurst	36 40	144 20	758	23.85	16	Do.
1245	Ararat	37 18	142 54	1,072	24.37	14	Do.
1246	Ballarat	37 36	143 54	1,438	27.06	17	Do.
1247	Gabo Island	37 36	149 54	40	38.66	13	Do.
1248	Buninyong	37 42	143 54	.....	26.02	3	Do.
1249	Melbourne	37 50	145 0	121	26.58	18	Do.
1250	Camperdown	38 12	143 12	770	30.48	6	Do.
1251	Portland	38 24	141 36	37	32.84	16	Do.
1252	Port Albert	38 36	146 42	30	27.74	12	Do.
1253	Cape Otway	38 54	143 50	300	38.40	13	Do.
1254	Kent's Group Islands	39 29	147 15	280	30.40	5	Do.
1255	Launceston	41 27	147 8	142	31.97	3	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

AUSTRALIA AND ADJACENT ISLANDS.

No.	Station.	Lat.	Long	Altitude.	Rain.	Years' obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
1256	Swansea	42 8N	148 5W	18	26.97	3	Ellery's Met. Obs.
1257	Port Arthur	43 9	147 54	55	45.75	5	Do.
1258	South Bruni	43 30	147 10	250	40.48	5	Do.
1259	Somerset	10 42	142 40	.....	86.82	2	Hann's Met. Zeit.
1260	Sweer's Island	17 7	139 41	33	40.63	2	Do.
1261	Gilbert River	17 54	143 0	.....	51.57	4	Do.
1262	Georgetown	17 57	143 40	.....	44.10	6	Do.
1263	Valley of Lagoons	18 40	147 10	.....	37.36	3	Do.
1264	Bloomsbury	20 14	149 5	.....	59.85	4	Do.
1265	Nebo	21 54	148 19	.....	38.58	4	Do.
1266	Mackay	21 10	149 5	.....	96.46	4	Do.
1267	Hollow	21 10	148 47	200	68.15	5	Do.
1268	Alexandria	21 0	149 0	.....	75.31	13	Do.
1269	Cedars	21 7	149 2	250	92.91	4	Do.
1270	Homebush	21 19	148 56	120	88.19	4	Do.
1271	Clermont	22 45	147 38	.....	32.32	6	Do.
1272	Rainworth	24 12	148 0	1,500	26.10	10	Do.
1273	Camboon	25 1	150 25	.....	30.32	5	Do.
1274	Taroom	25 38	149 45	.....	27.13	6	Do.
1275	Durah	26 20	150 28	.....	23.62	3	Do.
1276	Charleville	26 35	146 6	.....	17.76	4	Do.
1277	Roma	26 37	148 42	.....	22.05	6	Do.
1278	Condamine	26 57	150 6	.....	24.13	6	Do.
1279	Cape Moreton	27 0	153 32	.....	69.13	17	Do.
1280	Beechal Downs	27 9	145 0	.....	13.27	3	Do.
1281	Brisbane	27 27	153 3	110	52.36	17	Do.
1282	Dalby	27 30	151 15	.....	25.28	6	Do.
1283	Toowoomba	27 34	152 10	1,960	45.63	12	Do.
1284	Warwick	28 12	152 16	1,520	32.13	12	Do.
1285	King's Island	39 35	144 5	.....	58.66	5	Hann's Met. Zeit., 7.
1286	Auckland, New Zealand	36 50	174 50	258	43.62	4	Hann's Met. Zeit., 20.
1287	Pakawan	40 39	172 43	.....	108.54	9	Hann's Met. Zeit.
1288	Wellington	41 16	174 47	140	52.44	4	Do.
1289	Blenheim	41 30	174 2	.....	26.81	20	Do.
1290	Hokitika	42 41	170 59	12	112.91	9	Do.
1291	Christ Church	43 32	172 39	21	25.87	12	Do.
1292	Dunedin	45 52	170 31	550	34.84	4	Do.
1293	Napoleonville, New Caledonia	21 30	166 0	.....	63.38	2	Hann's Met. Zeit., 4.
1294	Port de France	22 20	166 39	.....	48.26	2	Hann's Met. Zeit.
1295	Delanasau, Fiji	16 38	178 37	77	98.29	15	Jo. Met. Soc., 13.
1296	Bua	16 42	178 34	700	93.55	5	Jo. Met. Soc.
1297	Alpha	16 44	180 0	1,000	130.80	4	Do.
1298	Vuna	16 50	179 53	30	118.58	4	Do.
1299	Rewa	17 13	178 36	.....	118.50	4	Do.
1300	Wakaia	17 30	179 4	.....	70.57	5	Do.
1301	Serua	18 10	177 51	.....	117.95	4	Do.

EAST INDIAN ARCHIPELAGO.

1302	Serang, Java	6 7	106 8	102	80.59	8	Van der Stok. Obs.
1303	Tanjerang	6 10	106 40	33	78.34	8	Do.
1304	Batavia	6 11	106 50	23	76.93	8	Do.
1305	Pasar Mingo	6 16	106 48	115	92.55	8	Do.
1306	Depok	6 24	106 51	302	118.54	8	Do.
1307	Buitenzurg	6 36	106 47	869	186.77	8	Do.
1308	Sinagar	6 50	106 50	1,785	126.03	7	Do.
1309	Tjikoppo	6 40	106 55	2,264	128.23	7	Do.
1310	Sindanglaja	6 43	107 4	3,524	126.42	8	Do.
1311	Kawah	7 11	107 26	6,404	144.76	7	Do.
1312	Telaga	7 10	107 25	5,105	162.64	7	Do.
1313	Soekawana	6 45	107 38	5,062	113.04	8	Do.
1314	Bandoeng	6 55	107 36	2,343	71.34	7	Do.
1315	Tjinjiroean	7 10	107 36	5,138	120.51	7	Do.
1316	Waspada	7 18	107 50	5,151	89.33	6	Do.
1317	Djatinangor	6 54	107 47	2,462	77.72	8	Do.
1318	Soemedang	6 50	107 57	1,450	120.55	8	Do.
1319	Manondjaja	7 20	108 20	810	125.59	8	Do.
1320	Banga Doewa	6 28	108 19	49	82.95	8	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

EAST INDIAN ARCHIPELAGO.

No.	Station.	Lat.	Long.	Altitude.	Rain.	Years obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
1321	Tegal	6 51N	109 8W	0	68.29	8	Van der Stok. Obs.
1322	Pekalongan	6 53	109 40	0	95.67	8	Do.
1323	Tjilatjap	7 44	109 0	0	163.63	8	Do.
1324	Banjoemas	7 32	109 17	33	122.83	8	Do.
1325	Gombong	7 36	109 30	72	140.01	7	Do.
1326	Kedong Kebo	7 41	110 2	148	106.18	8	Do.
1327	Pelantoengan	7 6	109 59	2,274	175.67	8	Do.
1328	Kendal	6 55	110 11	0	75.33	7	Do.
1329	Semarang	6 58	110 25	13	85.16	8	Do.
1330	Oenarang	7 8	110 23	1,027	182.05	8	Do.
1331	Tlogo	7 16	110 28	1,535	95.83	7	Do.
1332	Salatiga	7 20	110 30	1,932	103.26	8	Do.
1333	Magelang	7 29	110 13	1,256	128.66	8	Do.
1334	Klaten	7 42	110 35	692	83.46	8	Do.
1335	Bojolali	7 32	110 35	1,299	116.15	8	Do.
1336	Soerakarta	7 34	110 49	302	86.74	8	Do.
1337	Pati	6 45	111 1	56	60.63	7	Do.
1338	Rembang	6 45	111 20	0	54.18	8	Do.
1339	Toeban	6 52	112 5	0	48.11	8	Do.
1340	Ngawi	7 24	111 26	203	86.70	8	Do.
1341	Kediri	7 48	112 0	210	76.26	8	Do.
1342	Modjokerto	7 28	112 25	95	73.12	8	Do.
1343	Grisee	7 10	112 39	0	74.10	8	Do.
1344	Soerabaja	7 14	112 44	.....	67.01	8	Do.
1345	Malang	7 57	112 33	1,476	83.90	8	Do.
1346	Loemadjang	8 7	113 14	177	88.67	8	Do.
1347	Pasoeroean	7 38	112 56	13	49.91	8	Do.
1348	Probolinggo	7 44	113 13	33	45.95	8	Do.
1349	Besoeki	7 43	113 41	7	49.60	8	Do.
1350	Sitoebondo	7 41	114 2	262	45.12	8	Do.
1351	Maesan	8 0	113 50	1,214	99.49	8	Do.
1352	Adjoong	8 8	113 52	1,312	92.72	8	Do.
1353	Banjoewangi	8 13	114 23	16	51.26	8	Do.
1354	Bangkalan	7 2	112 44	16	79.41	8	Do.
1355	Pamekasan	7 10S	113 30	.....	67.99	8	Do.
1356	Kota Radja, Sumatra	5 32N	95 20	.....	70.12	8	Do.
1357	Edi	4 53	97 46	0	81.41	7	Do.
1358	Pangkalan	4 9	98 11	0	92.40	7	Do.
1359	Medan	3 35	98 41	46	79.13	8	Do.
1360	Bekalla	3 30	98 38	.....	106.81	8	Do.
1361	Sinkel	2 17	97 45	0	173.07	8	Do.
1362	Siboga	1 44	98 46	0	180.99	8	Do.
1363	Benkalis	1 28	102 6	0	95.67	7	Do.
1364	Sidempoean	1 23	99 15	928	86.62	8	Do.
1365	Tandjoeng	0 56	104 25	0	105.28	8	Do.
1366	Kota Nopan	0 37	99 46	1,420	86.93	5	Do.
1367	Rau	0 32N	100 3	978	83.51	7	Do.
1368	Pajakombo	0 15S	100 47	1,630	94.49	8	Do.
1369	Fort de Kock	0 21	100 28	3,041	100.24	8	Do.
1370	Pandjang	0 30	100 30	2,559	151.93	8	Do.
1371	Solok	0 48	100 40	1,233	90.94	8	Do.
1372	Loeboeselasi	0 57	100 38	3,281	141.62	7	Do.
1373	Padang	0 58	100 25	0	179.69	8	Do.
1374	Djambi	1 35	103 36	.....	94.92	8	Do.
1375	Palembang	2 59	104 45	.....	110.35	8	Do.
1376	Tebing	3 36	103 4	394	124.61	8	Do.
1377	Benkoelen	3 47	102 11	0	127.31	8	Do.
1378	Labat	3 48	103 31	328	143.90	8	Do.
1379	Bandar	4 5	103 22	.....	117.45	8	Do.
1380	Telok Betong	5 26	105 16	0	89.46	8	Do.
1381	Muntok	2 3	105 9	0	123.62	8	Do.
1382	Pand	2 45	107 38	0	115.64	8	Do.
1383	Dindang	3 5	107 48	0	97.29	7	Do.
1384	Boeding	2 40	107 55	0	125.01	7	Do.
1385	Manggar	2 52S	108 10	0	93.19	7	Do.
1386	Singkawang	0 55N	108 59	0	114.42	7	Do.
1387	Pontianak	0 1	109 20	.....	126.46	8	Do.
1388	Sintang	0 7N	111 32	.....	148.23	8	Do.
1389	Boentok	1 15S	114 30	.....	110.79	6	Do.
1390	Amoentai	2 15	115 10	.....	103.07	8	Do.
1391	Barabei	2 17	115 16	.....	97.13	7	Do.

TABLE LXXXII.—*Mean annual rainfall for different countries of the globe*—Continued.

EAST INDIAN ARCHIPELAGO.

No.	Station.	Lat.	Long.	Altitude.	Rain.	Years obs.	Authority.
		° ′	° ′	*Feet.*	*Inches.*		
1392	Pengaron	3 15 N	115 15 W	.....	104.92	8	Van der Stok. Obe.
1393	Bandjermasin	3 19 S	114 35	.....	91.73	8	Do.
1394	Elopura	5 48 N	118 15	.....	128.35	4	Hann's Met. Zeit., 18.
1395	Papar	5 42 N	115 57	.....	129.14	1	Hann's Met. Zeit.
1396	Segeri	4 38 S	119 30	10	134.73	6	Van der Stok. Obs.
1397	Pankadjene	4 51	119 32	10	154.33	8	Do.
1398	Tjamba	5 0	119 45	984	102.95	6	Do.
1399	Makasser	5 8	119 24	7	127.09	8	Do.
1400	Alloe	5 38	119 37	10	77.32	6	Do.
1401	Bonthain	5 33	119 55	3	52.83	6	Do.
1402	Saleijer	6 16	120 27	7	61.03	6	Do.
1403	Kadjang	5 23	120 23	26	95.27	6	Do.
1404	Bikeroe	5 12	120 8	804	126.80	6	Do.
1405	Balang Nipa	5 7 S	120 14	10	104.64	8	Do.
1406	Tontoli	1 0 N	120 53	7	94.92	6	Do.
1407	Limboto	0 40	123 5	.....	52.01	6	Do.
1408	Gorontalo	0 30	123 15	0	43.62	6	Do.
1409	Kwandang	1 10	122 50	0	94.57	6	Do.
1410	Menado	1 30	124 50	13	106.06	8	Do.
1411	Land Masarang	1 20	124 52	2,953	96.49	6	Do.
1412	Ternate	0 47	127 22	10	86 30	8	Do.
1413	Wahaai	2 50	129 30	0	94.13	6	Do.
1414	Kajeli	3 30	127 15	0	63.54	6	Do.
1415	Hila	3 32	128 15	0	84.45	6	Do.
1416	Amboina	3 42	128 10	0	148.11	8	Do.
1417	Saparoea	3 41	128 45	0	132.13	6	Do.
1418	Amahei	3 20	129 0	.....	105.19	6	Do.
1419	Banda Neira	4 32	129 53	0	113.28	8	Do.
1420	Koepang	10 10	123 34	.....	54.45	7	Do.
1421	Bima	8 22	118 40	.....	38.31	6	Do.
1422	Negara	8 20	114 39	.....	67.05	3	Do.
1423	Boeleleng	8 7 S	115 3	656	44.21	3	Do.
1424	Kema	1 22 N	125 4	0	56.81	3	Do.
1425	Linao	8 5	125 45	.....	150.72	1	Hann's Met. Zeit.
1426	Bohol	9 55	124 32	.....	49.47	2	Do.
1427	Manilla	14 36 N	120 40	.....	87.43	4	Do.

205. If we carefully examine Plate XXXIII in connection with Table LXXXII, we shall be able to detect certain conditions which contribute to produce an abundant rainfall, and other conditions which are unfavorable to rainfall. Among the conditions which contribute to an abundant rainfall are the following:

(A) The northeast and southeast trade winds on approaching the belt of calms which always prevail near the equator are gradually deflected upward, giving rise to a vertical ascending current within the belt of calms. This ascending current becomes cooled by expansion until its vapor is condensed, causing an abundant fall of rain, and the belt of calms becomes a belt of rain which from its position is called the equatorial rain belt. This belt of calms oscillates towards the north or towards the south with the movement of the sun in declination, so that over the ocean the equatorial rain belt has a breadth of 9 or 10 degrees within which it rains almost every day. As we recede from this rain belt, either northward or southward, the number of rainy days diminishes until we reach a latitude where the trade winds are more steady, and here rain is almost unknown.

The existence of this rain belt is well known to navigators, and its position at different seasons of the year is shown by Maury's Pilot Charts and by the charts of the U. S. Hydrographic Office. It is shown with the greatest distinctness by the charts published by the English Meteorological Committee for nine 10-degree squares covering the Atlantic Ocean, from 20° north latitude to 10° south latitude. Table LXXXIII shows the mean annual distribution of rain in that part of the Atlantic Ocean situated between the meridians of 10° and 40° west from Greenwich, and between the parallels of 26° north latitude and 10° south latitude. The numbers in the table represent the average annual number of rains corresponding to a hundred observations reported in the log books examined, the observations being made three times each day.

The stars in the table denote squares covered by land.

From this table we see that a little north of the equator there is a belt several degrees in breadth within which there is a remarkable persistence of rainy days, and at a distance of a few degrees on each side of this belt rain rarely occurs.

TABLE LXXXIII.—*Number of rains in a hundred observations over the Atlantic Ocean. Longitude from Greenwich.*

Latitude.	10° to 15°.	15° to 20°.	20° to 25°.	25° to 30°.	30° to 35°.	35° to 40°.
20° to 18° N.	*	0	0	1	2	3
18 16	*	0	1	1	2	3
16 14	*	1	2	2	3	1
14 12	*	1	3	3	3	2
12 10	*	5	6	6	5	4
10 8	4	8	11	12	9	9
8 6	12	10	15	17	13	7
6 4	8	11	18	17	15	8
4 2 N.	4	11	15	15	10	6
2 0	2	7	9	7	11	3
0 2 S.	0	3	4	5	6	5
2 4	0	2	5	6	5	1
4 6	1	2	3	4	5	*
6 8	1	1	4	2	5	*
8 10 S.	1	2	1	3	5	*

206. In order to show the changes in the position of this rain belt, corresponding to the motion of the sun in declination, I have prepared Table LXXXIV, which shows for each month of the year the average number of rains corresponding to a hundred observations (observations being made three times a day) between the meridians of 20° and 30° west from Greenwich.

TABLE LXXXIV.—*Number of rains in a hundred observations each month between* 20° *and* 30° *west longitude.*

Latitude.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20° to 18° N.	1	0	0	0	0	0	0	0	2	0	1	1
18 16	1	0	0	0	0	0	1	2	4	2	1	1
16 14	0	0	0	0	0	0	0	10	4	2	2	1
14 12	0	0	0	0	0	0	5	13	9	7	3	1
12 10	1	0	0	0	1	2	13	18	14	12	5	1
10 9	3	0	0	0	3	8	23	27	22	20	14	5
9 8	0	0	0	0	3	20	28	28	20	20	21	6
8 7	8	0	0	1	6	18	31	20	18	27	28	16
7 6	14	2	1	1	13	30	25	15	17	22	27	23
6 5	19	3	8	9	24	26	13	8	18	26	25	21
5 4	25	14	16	19	30	23	4	2	15	24	26	18
4 3	32	23	19	25	26	18	6	1	8	16	16	16
3 2	22	26	26	33	20	8	1	1	2	6	8	6
2 1 N.	25	23	18	19	13	2	2	1	0	3	4	5
1 0	19	14	12	17	9	0	0	0	0	1	3	6
0 2 S.	5	8	10	12	9	1	1	0	0	1	2	2
2 4	4	7	10	13	10	5	3	2	0	2	2	2
4 6	3	2	6	6	3	5	4	1	2	2	1	0
6 8	1	4	8	6	4	2	3	0	4	2	0	0
8 10 S.	1	1	0	0	4	4	0	2	6	1	0	0

We see from this table that for several months there is a certain latitude where the number of rains amounts to 30 or more in a hundred observations (or 33 days); that is, rain falls almost daily. We also see that the center of the belt of rain oscillates from about 2° north latitude near the close of winter to 9° north latitude near the close of summer, and the belt is 6° or 7° in breadth. Within the limits of the trade winds, as long as these winds maintain their usual course, rain is of rare occurrence. Beyond the limits of the trade winds, rains increase in fre-

quency; and in the Atlantic Ocean beyond latitude 45° north or 40° south they are nearly as frequent as within the belt of equatorial calms. Over the continents, the form of this rain belt is much more irregular than it is over the ocean and it experiences greater changes in position resulting from the sun's motion in declination. For this there are two reasons, viz: the earth is more readily heated by the sun's rays than the water, and the precipitation of the vapor of the atmosphere is greatly influenced by mountains. Nevertheless a slight examination of Plate XXXIII will enable us to trace this equatorial rain belt across the continents. We find a rain belt crossing the continent of Africa within which the mean annual rainfall is not less than 50 inches, and at numerous places on the Atlantic coast of Africa the annual rainfall exceeds 75 inches. Near the Atlantic coast, the center of this rain belt is about 4° north of the equator, but near the eastern coast the center of the belt coincides nearly with the equator. This belt oscillates with the movement of the sun in declination. According to Keith Johnson the center of this belt in July is in about 7° north latitude, and in January it is in about 9° south latitude.

The winds of Central Africa show very little of the regularity of the trade winds over the Atlantic Ocean; but on the north side of this rain belt the prevalent winds are from the north, and most frequently from the northeast, while on the south side of this rainbelt the prevalent winds are from the south, and are about equally divided between southeast, south, and southwest. According to Speke's observations made in 1861–'62, in Central Africa, latitude 1° 37′ north, longitude 32° 20′ east, the prevailing winds for each month of the year were—

Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
N. E.	N. E.	E. by N.	Var.	E. by S.	S. E.	S. E.	S. E.	Var.	Var.	N. E.	N. E.

We find a similar but much broader rain belt crossing the American continent and extending southward to latitude 31°, and within this belt there are extensive districts having an annual rainfall exceeding 75 inches, showing a greater aggregate rainfall for South America than for Africa.

207. (B). A second cause for abundant rainfall is the influence of mountains. When a strong wind meets a mountain, it is forced up the side of the mountain; it is thus elevated into a colder region and its vapor is precipitated by the cold of elevation. On a mountain of moderate elevation, the rainfall is usually greater than it is at the level of the sea; and at a certain height the rainfall is from two to three times as great as it is near the base of the mountain. We find this principle exemplified in all parts of the world. Table LXXXV contains some examples of this kind. Column 2 gives the name of the mountain; column 3 gives its altitude in English feet, and column 4 gives the annual rainfall; column 5 gives the name of a station at a much lower level, generally the lowest station that could be found, distant from the mountain not more than 25 or 50 miles; column 6 gives the altitude of the station, column 7, the annual rainfall, and column 8 gives the ratio of the numbers in columns 4 and 7.

The first examples in the table are mountains having a form somewhat conical, whose peaks rise so much above the surrounding country that there is nothing to interfere with the free movement of the winds. From these examples we learn that on a mountain from 4,000 to 10,000 feet in height, the average rainfall is more than double what it is at neighboring places near the sea level. Several of the mountains included in the table are in the vicinity of the Alps, and the excessive rainfall is not restricted to a small geographical area, but extends over a country 400 or 500 miles in length. The station on the island of Mauritius, at which the annual rainfall exceeds 100 inches, is less than 2,000 feet in elevation, but this does not represent the total height of the mountain, which is 2,700 feet. The extremely small rainfall at Jamestown, on St. Helena, is probably due to its situation on the northwest side of the island, where it is protected by the mountain from the strong southeast trade winds which in that vicinity are seldom interrupted. Port Louis, Mauritius, is similarly situated with respect to the neighboring mountains. The last two examples in the table represent passes over the Alps, and we see that they share in the liberal rainfall which prevails generally over those mountains.

TABLE LXXXV.—*Influence of mountains upon rainfall.*

No.	High station.	Elevation.	Rain.	Low station.	Elevation.	Rain.	Ratio.
		Feet.	*Inches.*		*Feet.*	*Inches.*	
1	Mt. Washington, New Hampshire, U. S.	6,285	83.86	Burlington, Vermont	268	28.76	2.92
2	Mt. Hamilton, California, U. S.	4,250	33.74	San José, California	94	12.95	2.61
3	Ben Nevis, Scotland	4,407	141.76	Laggan, Scotland	821	49.39	2.87
4	Puy de Dome, France	4,806	60.82	Base of mountain	1,273	25.54	2.38
5	Plantade, Pic du Midi, France	7,763	86.98	Pau, France	679	33.07	2.63
6	Brocken, Germany	3,743	58.59	Brunswick, Germany	320	23.70	2.47
7	Schneekoppe, Germany	5,246	55.12	Eichberg, Germany	1,142	25.02	2.20
8	Wendelstein, Germany	6,027	58.74	Munich, Germany	1,676	29.10	2.02
9	Obirgipfel, Austria	7,047	62.45	Gratz, Austria	1,129	22.76	2.74
10	Rigi, Switzerland	5,873	67.49	Geneva, Switzerland	1,335	29.53	2.29
11	Säntis, Switzerland	8,215	61.84	Geneva, Switzerland	1,335	29.53	2.09
12	Curepipe, Mauritius	1,700	165.95	Beauvallon, Mauritius	240	60.48	2.74
13	Longwood, St. Helena	1,765	41.54	Jamestown, St. Helena	40	5.31	7.82
14	Grand St. Bernard, Switzerland	9,413	63.36	Geneva, Switzerland	1,335	29.53	2.14
15	Colle di Valdobbia, Italy	8,474	59.29	Turin, Italy	902	32.54	1.82

208. A range of mountains running in a direction nearly at right angles to that of the prevalent wind produces an effect similar to that of a detached conical mountain, but its influence is much more conspicuous upon a rain map. We find this principle illustrated in every country where there are mountains, but it is especially noticeable in Europe. The winds from the Atlantic Ocean, warmed by the waters of the Gulf Stream and striking against the range of mountains on the coast of Norway, are deflected upward and the vapor is condensed, causing an annual rainfall of more than 25 inches along the entire coast of Norway, and for a considerable distance there is a rainfall of from 50 to 75 inches. A similar effect is produced on the western coast of Great Britain, where the annual rainfall exceeds 50 inches, but this great rainfall is partly due to cause (C), to be mentioned hereafter. The mountains on the western coast of Spain and Portugal are also marked by a rainfall exceeding 50 inches; and the Alps, the Pyreenes, the Caucasus and several minor ranges of mountains are similarly marked.

The mountains near the Pacific coast of the United States exert a similar influence upon the rainfall, and in order to exhibit the effects more minutely than is shown by Plate XXXIII, I have prepared Plate XXXIV, which illustrates a variety of principles to be considered hereafter. The influence of the Sierra Nevadas upon the rainfall is conspicuously shown on this map. This range of mountains runs nearly parallel to the coast of California, at a distance of about 150 miles, and has an average elevation exceeding 6,000 feet, while in many places it rises to a height of more than 10,000 feet. This range of mountains is marked by a rainfall of more than 50 inches, while on either side of it, along its southern portion, at a distance of only 50 miles, the annual rainfall is less than 10 inches. In crossing this range of mountains the amount of rainfall increases steadily with the elevation. Table LXXXVI shows some of the stations on the Central Pacific Railroad from Sacramento over the Sierras eastward into Nevada. Column 1 gives the names of the stations; column 2 gives their elevation above the sea; column 3 gives the mean annual rainfall at the stations named, and column 4 shows the number of years of observations from which the average is derived.

TABLE LXXXVI.—*Rain on the Sierra Nevada Mountains, California.*

	Elevation.	Rain.	Years Obs.		Elevation.	Rain.	Years Obs.
	Feet.	*Inches.*			*Feet.*	*Inches.*	
Sacramento	35	20.32	37	Cisco	5,939	57.55	14
Rocklin	249	19.45	16	Summit	7,017	47.95	13
Auburn	1,363	33.15	16	Truckee	5,819	29.52	14
Colfax	2,421	45.16	16	Boca	5,531	17.35	13
Alta	3,612	43.76	14	Carson City	4,630	11.91	7
Emigrant Gap	5,230	51.41	17	Winnemucca	4,358	8.85	8

The greatest rainfall at any of these stations is 57.55 inches, and this occurs before reaching the summit of the Pass. As we descend the mountain on its eastern side, the rainfall diminishes much more rapidly than it increases with the ascent on the western side. This peculiarity will be noticed under article 216.

209. The mountains of India exert an influence upon the rainfall in some respects more remarkable than any other mountains on the face of the globe. In order to exhibit the phenomena of this region more distinctly than is shown on Plate XXXIII, I have prepared Plate XXXV, which shows a region of excessive rainfall along the Malabar coast of India, and a still more remarkable rainfall on the mountains northeast of Calcutta. Over an area 350 miles in diameter the mean annual rainfall exceeds 75 inches, and near the center of this area at Cherra Poonjee, the mean annual rainfall, deduced from observations of 25 years, is 475 inches. Cherra Poonjee is situated on the Khasi Hills, 200 miles north of the Bay of Bengal, and at an elevation of 4,455 feet above the sea. Nearly all of the rain at this station falls during the warmer months of the year, and with a southerly wind from the Bay of Bengal. This will be seen from Table LXXXVII, in which column 2 shows the average rainfall at Cherra Poonjee for each month of the year; column 3 shows the average direction of the wind at Calcutta, and column 4 shows its average direction at Chittagong, situated at the head of the Bay of Bengal and exactly south from Cherra Poonjee.

TABLE LXXXVII.—*Rainfall at Cherra Poonjee, Bengal.*

	Rain, Cherra Poongee.	Winds, Calcutta.	Winds, Chittagong.		Rain, Cherra Poonjee.	Winds, Calcutta.	Winds, Chittagong.
January.....	0.69	N. 38° W.	N. 26° W.	July	121.53	S. 11° E.	S. 42° E.
February	2.65	S. 81° W.	N. 40° W.	August.....	78.28	S. 17° E.	S. 31° E.
March	9.06	S. 32° W.	S. 60° W.	September	54.64	S. 27° E.	S. 27° E.
April.....	29.32	S. 3° W.	S. 13° W.	October	14.20	N. 48° W.	N. 19° W.
May	51.65	S. 11° E.	S. 7° W.	November.....	2.00	N. 17° W.	N. 19° W.
June.....	111.53	S. 4° E.	S. 30° E.	December	0.34	N. 26° W.	N. 24° W.

Thus we see that 94 per cent. of the annual rain at Cherra Poonjee falls during the 6 months from April to September inclusive; and during these months the average winds at Calcutta and Chittagong are from the south, while during most of the other 6 months of the year the average winds are from the northwest. When the wind in the Bay of Bengal blows from the south, rain falls almost incessantly on the Khasi Hills; and when the wind changes to the west or northwest, the rain ceases almost entirely. These facts indicate that the rainfall is due to an upward deflection of the winds as they encounter a range of mountains, and the extraordinary amount of the rainfall is due to an unusual combination of circumstances, viz: the high temperature of the air, its great humidity coming directly from the Indian Ocean, the proximity of the mountain to the ocean, and the abruptness of the mountain, which rises 4,315 feet from Sylhet to Cherra Poonjee, a distance of less than 30 miles.

In ascending the Khasi Hills from the low grounds on the west, we find a steady increase in the annual rainfall. Table LXXXVIII shows the annual amount of rain at a series of stations increasing gradually in elevation from the banks of the Ganges up to a height of 5,000 feet.

TABLE LXXXVIII.—*Rain on the Khasi Hills, India.*

Station.	Elevation.	Rainfall.	Station.	Elevation.	Rainfall.
	Feet.	*Inches.*		*Feet.*	*Inches.*
Rampore Bouleah	35	59	Cherra Poonjee	4,455	475
Mymensingh	60	94	Shillong.....	4,792	85
Sylhet	140	155	Kohima	5,000	78

We see that at stations higher than Cherra Poonjee the rainfall is comparatively small, and the decrease is so rapid as to indicate that there must be a special cause for the extraordinary

rainfall at Cherra Poonjee. This cause is apparently the abruptness with which the mountain rises from the low lands on the south.

210. In order to obtain further information respecting the influence of the mountains of India upon rainfall, I have selected all the Indian rain stations having an altitude equal to that at Cherra Poonjee. These stations are shown in Table LXXXIX, which gives the altitude of each station in English feet, and the mean annual rainfall. I have also included two stations beyond the limits of India.

TABLE LXXXIX.—*Rainfall at mountain stations in India.*

No.	Station.	Elevation.	Rain.	No.	Station.	Elevation.	Rain.
		Feet.	*Inches.*			*Feet.*	*Inches.*
1	Leh, Cashmere	11,500	2.62	16	Pauri, N. W. Provinces	5,230	49.95
2	Gilgit, Cashmere	4,890	3.71	17	Kotgahr, Punjab	5,000	66.27
				18	Dharmsala, Punjab	4,500	124.55
3	Niti, Gurhwal	11,460	7.06				
4	Kilba, Punjab	8,500	22.35	19	Darjeeling, Bengal	6,912	120.33
5	Chakrata, N. W. Provinces	7,050	60.24	20	Kohima, Assam	5,000	78.47
6	Simla, Punjab	6,953	70.65	21	Kurseong, Bengal	4,840	150.11
7	Mussooree, N. W. Provinces	6,880	94.35	22	Shillong, Assam	4,792	85,39
8	Kasauli, Punjab	6,835	69.34	23	Mongpoo, Bengal	4,700	125.37
9	Dalhousie, Punjab	6,740	83.38	24	Cherra Poonjee, Assam	4,455	475.89
10	Naini, Tal, N. W. Provinces	6,400	91.63				
11	Murree, Punjab	6,344	54.90	25	Ootacamund, Madras	7,250	44.88
12	Ranikhet, N. W. Provinces	6,069	48.43	26	Wellington, Madras	6,200	46.56
13	Champawat, N. W. Provinces	5,546	57.41	27	Newera Eliya, Ceylon	6,150	100.07
14	Almora, N. W. Provinces	5,494	38.90	28	Mahableshwar, Bombay	4,540	260.87
15	Pithoragarh, N. W. Provinces	5,373	47.91	29	Uttray Mullay, Travancore	4,500	267.21
				30	Shevaroy Hills, Madras	4,500	60.82

These stations differ greatly in geographical position and are naturally divided into four groups. The first two stations are situated on the northeast side of the dividing ridge of the Himalaya Mountains, and the southwest winds from the Bay of Bengal have been drained of their moisture by passing over a range of high mountains before reaching these stations. Such stations may be said to be situated in the shadow of the mountain.

The next sixteen stations (Nos. 3–18) are situated in Northern India on the southwest slope of the Himalaya Mountains. Niti is situated in latitude 30° 48′ and longitude 79° 34′, which is near the dividing ridge of the mountains, but according to my maps is a little on the southwest side. All of the sixteen stations are situated within about 100 miles of the dividing ridge of the mountains, and the average rainfall is decidedly less than it is near the Khasi Hills. This diminished rainfall may be ascribed to the fact that the stations are all considerably farther from the Bay of Bengal than the Khasi Hills, and they are too far westward to feel the full effect of the south winds which blow from the ocean. At only one of the stations does the rainfall amount to 100 inches, and this station is the one which has the least elevation.

The next six stations (Nos. 19–24) are all situated within 250 miles of Cherra Poonjee, and there is a noticeable contrast between the rainfall at the latter station and the other five stations.

The last six stations (Nos. 25–30) are all situated near the Malabar coast of Hindostan, with the exception of No. 27, which is in the interior of Ceylon. Nos. 25 and 26 are situated about 70 miles from the Malabar coast, and are partly under the shadow of mountains nearer the coast. No. 30 is entirely under the shadow of the coast range of mountains. Nos. 28 and 29 are near the summit of the coast range, where there is nothing to obstruct the southwest winds which come from the Indian Ocean during the summer monsoon. It will be noticed that in each of the groups 2, 3, and 4 the greatest rainfall occurs at a station whose altitude is almost exactly 4,500 feet, indicating that this is the height at which the mountains of India produce the greatest effect on rainfall.

211. In order to determine the effect of elevation upon rainfall, it is important to know not merely the height of the stations reported, but also the character of the surrounding country; for the effect of a mountain upon rainfall is not restricted to the limits of the mountain, but extends to a considerable distance beyond it, so that a station of small elevation may have an enormous

rainfall which is quite independent of its altitude. This fact is illustrated by the Rainfall Tables of the British Isles, published by the Meteorological Council. More than 90 per cent. of all the stations (366 in number) have an elevation less than 750 feet, but many of them exhibit the effects of a neighboring mountain several thousand feet in elevation. Table XC exhibits all the stations in this collection included within a belt 30 miles in breadth, extending entirely across the island from west to east on the northern margin of England.

TABLE XC.—*Rainfall in the north of England.*

Station.	Elevation	Rain.	Station.	Elevation	Rain.
	Feet.	*Inches.*		*Feet.*	*Inches.*
Cockermouth, Higham	478	45.00	Windermere	322	68.36
Cockermouth, Whinfell Hall	265	53.05	Ullswater	490	56.21
Bassenthwaite	310	51.08	Sedbergh	400	55.26
Keswick, Derwent Island	280	54.83	Kirkby Stephen	574	40.09
Keswick Post-Office	270	60.53	Catterick	350	28.00
Seathwaite	422	139.29	Malton	75	28.68
Grasmere, High Close	553	82.07	Egglescliffe	80	26.66
Monk Coniston Park	150	76.77	Whitby	184	26.92

This table shows a station only 422 feet in elevation where the mean annual rainfall, deduced from 15 years' observations, is 139.29 inches, which is the greatest known rainfall at any station in Europe. This remarkable rainfall is due to the influence of two neighboring mountains—Skiddaw, with an elevation of 3,166 feet, and Helvellyn, with an elevation of 3,055 feet.

212. (C.) A third condition favorable to an abundant rainfall is proximity to the ocean, especially when the prevalent wind comes from the ocean. This cause is usually combined with cause (B) in such a manner that it is difficult to decide how much of the effect is due to each cause separately; but in Northern Europe we find extensive districts so nearly level as to exhibit the operation of this cause too distinctly to be questioned. From the North Sea to the Ural Mountains, between the parallels of 52° and 58° of latitude, is a belt 2,000 miles long and 400 miles wide, within which the greatest elevation of the land barely amounts to 1,000 feet, and the changes of level are so gradual as to exert no appreciable influence upon the rainfall. Table XCI shows the rainfall at a large number of stations, beginning with Norderney, a small island in the North Sea near the northern boundary of Holland, and extending to the Ural Mountains, following nearly the parallel of Hamburg.

TABLE XCI.—*Rainfall in Northern Europe.*

No.	Station.	Elevation.	Rain.	No.	Station.	Elevation.	Rain.
		Feet.	*Inches.*			*Feet.*	*Inches.*
1	Norderney, Germany	.....	36.57	8	Pinsk, Russia	459	23.46
2	Cuxhaven, Germany	.....	31.54	9	Gorki, Russia	689	20.43
3	Hamburg, Germany	85	28.82	10	Koursk, Russia	689	16.81
4	Schwerin, Germany	161	22.76	11	Kasan, Russia	262	15.28
5	Berlin, Germany	131	23.50	12	Samara, Russia	197	15.09
6	Zechen, Germany	404	23.36	13	Polibino, Russia	305	14.69
7	Warsaw, Russia	394	22.72	14	Ekaterinburg, Russia	886	13.35

We see that on going eastward from the North Sea, for the first 100 miles the rainfall diminishes rapidly; it afterwards diminishes more slowly and somewhat irregularly, but in the eastern part of Russia the average rainfall is less than half of that in the neighborhood of the North Sea.

213. (D.) Capes and headlands projecting considerably into the ocean generally show a rainfall greater than interior stations only a few miles distant. We see this principle exemplified in all parts of the world, but in selecting illustrations it is important to avoid stations which are much elevated above the sea. Table XCII shows six stations on the Atlantic coast of the United States which are fully exposed to the winds from the ocean, and opposite to them I have placed inland stations which are supposed to represent the average rainfall for their vicinity. The last column

of the table shows the ratio of the numbers in columns 3 and 6. We see that the first group of stations shows the average rainfall 30 per cent. greater than the second group. The number given for Cape Charles is derived from observations of only one year, and is probably somewhat too great. Similar examples may be found in all parts of the world.

TABLE XCII.—*Rainfall near the Atlantic coast of the United States.*

Cape stations.	Elevation.	Rain.	Inland stations.	Elevation.	Rain.	Ratio.
	Feet.	*Inches.*		*Feet.*	*Inches.*	
Thatcher's Island, Mass.....	48	48.07	Newburyport, Mass.....	46	39.35	1.22
Sandy Hook, N. J	28	51.26	New York City.....	164	42.17	1.22
Cape May, N. J.....	27	47.63	Fort Delaware	10	40.08	1.19
Cape Charles, Va.....	160	83.64	Norfolk, Va	30	51.75	1.62
Cape Hatteras, N. C	12	75.44	Goldsborough, N. C	102	54.47	1.39
Cape Lookout, N. C.....	.....	75.55	Wilmington, N. C	52	57.92	1.30

214. (E.) The great and nonperiodic depressions of the barometer are always accompanied by a considerable fall of rain, and the average tracks of these depressions are marked by an excess of rainfall. This cause is generally so blended with causes (B), (C), and (D) that it is liable to be overlooked, but a careful examination will enable us to detect its influence. Plates XX, XXII, XXVIII, and XXIX of Chapter II show barometric depressions over the Pacific Ocean in the neighborhood of the Aleutian Islands. The precipitation of the vapor of the atmosphere upon these islands appears to be one of the principal causes of the great barometric fluctuations over the Pacific Ocean; and the centers of most of the violent storms of this ocean pass near the Aleutian Islands. As these storms advance eastward, they generally meet the North American coast between the parallels of 55° and 60°. Here they encounter a range of mountains, by which the moist air of the ocean is deflected upward and there results an abundant rainfall. The great rainfall on this part of the American coast is largely due to the mountains near the coast; but the precipitation takes place on that particular part of the coast, because this is where the tracks of storms from the Pacific Ocean most frequently pass, and the position of these tracks is largely determined by causes which operated on the storms before they reached the American coast. If these storms in their progress eastward had pursued a more southerly course, there would have been an equal and perhaps greater rainfall near the coast (for the same range of mountains follows the coast down to California), but the greatest rainfall would have been found in a more southern latitude than it now has.

Causes somewhat similar appear to operate on the coast of Europe. We have seen from Plate XXVII, Chapter II, that the centers of the great barometric depressions over the Atlantic Ocean show a tendency to collect in groups, and one of these groups is situated north of the British Isles in latitude about 60°. The centers of great barometric depressions tend towards this region, on account of the great rainfall caused by the mountains on the north of Scotland and the adjacent islands. These storms in their progress eastward impinge upon the mountains of Norway, and most frequently meet the Norwegian coast between the parallels of 60° and 62°. This is a region where causes (B), (C), and (D) combine to produce an abundant rainfall. Here there are high mountains rising abruptly from the sea, and the coast projects furthest towards the warm waters of the Gulf Stream. But in addition to these causes there is a concentration of storms on this part of the Norwegian coast, owing to the influence of the islands in the neighborhood of Scotland. If Great Britain with all the adjacent islands were covered by the waters of the ocean, there would doubtless still be an abundant rainfall on the coast of Norway, but it is probable that the rainfall would not rise to 75 inches as it does at present.

We have seen in Chapter I, Table XX, that storms in the United States frequently originate in the Gulf of Mexico, and advance sometimes toward the north, but generally toward the northeast. These storms are usually accompanied by a very heavy rainfall, and a large part of the rainfall in the United States, east of the meridian of 100°, comes with these storms. Many of the storms which have their origin in the Gulf of Mexico, or near the West India Islands, follow a course nearly parallel with the American coast toward Nova Scotia and Newfoundland, and increase the annual rainfall of these countries particularly upon the southeast side. The same

storms frequently advance toward South Greenland, and cause a much greater annual rainfall than is usual in that latitude. The mean annual rainfall at Iviktut in latitude 61° 12′, from nine years' observations, is 45¾ inches.

Similar storms originate near the Philippine Islands, and as they pursue their northeast course they add considerably to the annual rainfall of the coasts of China and Japan.

The force of these considerations will probably be better appreciated when we examine, in article 224, regions where storm tracks do not pass.

215. Among the conditions which are unfavorable to rainfall are the following:

(F.) Fresh winds blowing in a nearly uniform direction throughout the year, such as prevail within a portion of the system of trade winds, especially in mid-ocean. We have seen from Tables LXXXIII and LXXXIV, that over the Atlantic Ocean, on each side of the equatorial rainbelt, there is an extensive region where rain is almost unknown. Within this region is included the Island of Ascension in latitude 7° 55′ south and longitude 14° 25′ west. This is a small but mountainous island, the highest peak rising 2,820 feet above the sea. In the volume entitled "Remarks to accompany the monthly charts for nine 10° squares of the Atlantic Ocean," is a detailed account of two years' meteorological observations at this island. The total rainfall for one of these years was 2.31 inches, and for the other year it was 4.30 inches. Table XCIII shows the average direction and velocity of the wind for each month of the year.

TABLE XCIII.—*Winds at Ascension Island.*

Month.	First year.		Second year.		Month.	First year.		Second year.	
	Direction.	Velocity.	Direction.	Velocity.		Direction.	Velocity.	Direction.	Velocity.
January.....	S. 45° E.	26.2	S. 51° E.	26.0	July	S. 46° E.	29.2	S. 60° E.	27.6
February....	43	24.2	50	23.7	August.....	47	31.7	49	29.3
March.....	47	23.9	51	23.6	September ..	48	28.0	55	28.4
April.....	49	25.8	54	27.6	October	50	26.3	58	25.6
May	47	26.1	54	29.8	November ...	51	26.8	54	25.7
June	52	26.9	56	25.8	December ...	47	27.3	52	26.4

We see that the mean direction and velocity of the wind changed very slightly from month to month, and the observations of the second year differed but little from those of the first. Moreover, the observations of the successive days of each month agreed almost as well as the mean results for the months. During the entire period of two years there were only 136 hours (less than 1 per cent. of the whole number of hours) during which the wind did not blow from some point between south and east, and there were only three hours during which the anemometer registered a perfect calm.

From this example we learn that in mid-ocean, where there are fresh winds blowing at all times in a nearly uniform direction, there is almost no rainfall. Such is the condition of things which prevails over the Atlantic Ocean within the region where the trade winds blow with considerable force and are seldom interrupted. Over the continents, where the disturbing causes are so numerous, the operation of this principle is not so distinctly seen.

216. (G.) A second condition which is unfavorable to rainfall is a position on the leeward side of a range of mountains running in a direction nearly at right angles to that of the prevalent wind. We have seen, article 208, that such a range of mountains causes an abundant rainfall on the windward side of the mountains; but when the air has passed over the summit of the range it has lost a large part of its vapor, and when it descends on the leeward side it is warmed by coming under increased pressure, and it becomes a dry wind from which little or no rain can result. While, then, an elevated range of mountains causes excessive rainfall on the windward side it causes a deficiency of rain on the leeward side. This principle is strikingly exemplified in South America. The trade winds, after passing nearly across the continent, encounter the Andes by which they are forced upward to a great height and lose nearly all of their vapor; and when the air descends on the western side it is extremely dry, and along the Pacific coast there is a narrow belt which is almost rainless. This effect is shown on Plate XXXIII from near the equator to latitude 31° south. The same effect is not produced on the north side of the equator, because near the Isthmus of Panama the breadth of the continent is so small that the winds from the

Pacific Ocean appear to be drawn in to meet the strong winds which come from the Atlantic, and which ascend over the Andes. Westerly winds therefore prevail over the Pacific Ocean to a distance of several hundred miles from the coast down as far as the equator.

Another remarkable illustration of the same principle is seen on the Malabar coast of Hindostan. The winds from the ocean encountering the coast range of mountains cause a rainfall amounting in some places to 250 inches annually. When this air descends on the eastern side of the range, it is very dry, and the mean annual rainfall is reduced to about 25 inches and in some places to less than 25 inches.

We see the same principle exemplified on the northwest coast of the United States, north of latitude 41°; it is exemplified by the Sierra Nevadas along the eastern margin of California; and if we had observations sufficiently numerous we should probably find a similar effect produced by the Rocky Mountain Range, although on account of the dryness of the air in the Salt Lake Basin, the contrast between the rainfall on the east and west sides of the Rocky Mountain Range is much less than in the case of the Sierra Nevadas.

The hygrometric observations made at the stations of the U. S. Signal Service show the effect of the different ranges of mountains upon the moisture of the atmosphere in its progress from the Pacific Ocean to the valley of the Mississippi. Table XCIV shows the mean relative humidity at the stations of the Signal Service west of the meridian of 97° from Greenwich.

The lines of equal relative humidity for this part of the United States are shown on Plate XXXVI, Fig. 1. The range of mountains near the Pacific coast produces only a small effect upon the humidity of the air; but south of latitude 45° the Sierra Nevadas produce a very decided effect, the average humidity over a large district of the Salt Lake Basin being less than 50 per cent., and near the center of this district the average humidity is less than 40 per cent. There is a slight increase of humidity in crossing the dividing ridge of the Rocky Mountains, but when the air descends upon the eastern side of the mountain its humidity again becomes reduced to less than 50 per cent., and the humidity rapidly increases as we advance eastward.

Nearly every considerable range of mountains affords an illustration of principle (G), but in many cases the result is complicated by the operation of other causes to be named hereafter.

TABLE XCIV.—*Mean relative humidity at the Signal Service stations west of longitude* 97°.

Stations.	Lat.	Long.	Altitude.	Relative humidity.	Stations.	Lat.	Long.	Altitude.	Relative humidity.
	° ′	° ′	*Feet.*			° ′	° ′	*Feet.*	
St. Vincent	48 56	97 14	804	81	Cape Mendocino	40 26	124 24	637	83
Fort Assinniboine	48 32	109 42	2,720	60	Red Bluff	40 10	122 15	337	55
Tatoosh Island	48 23	124 44	86	86	Denver	39 45	105 0	5,294	49
Poplar River	48 8	105 10	2,030	80	Pike's Peak	38 50	105 2	14,134	70
Fort Buford	48 0	103 56	1,930	70	Sacramento	38 35	121 30	64	67
Fort Totten	47 57	98 57	1,500	75	Montrose	38 30	107 56	5,825	56
Fort Benton	47 50	110 40	2,681	62	Frisco	38 25	113 16	6,315	45
Spokane Falls	47 40	117 25	1,909	70	West Las Animas	38 4	103 12	3,899	61
Fort Shaw	47 31	111 48	3,550	61	Pioche	37 57	114 26	5,779	39
Fort Maginnis	47 12	109 10	4,340	53	San Francisco	37 48	122 26	60	75
Olympia	47 3	122 53	36	79	Dodge City	37 45	100 0	2,517	63
Bismarck	46 47	100 38	1,694	70	Keeler	36 35	117 50	3,622	42
Helena	46 34	112 4	4,069	62	Santa Fé	35 41	105 57	7,026	44
Dayton	46 19	117 56	1,683	67	Fort Elliott	35 30	100 21	2,650	55
Fort Canby	46 16	124 4	179	87	Fort Sill	34 40	98 23	1,200	65
Lewiston	46 8	117 5	785	62	Prescott	34 33	112 28	5,389	49
Fort Custer	45 42	107 34	3,040	62	Los Angeles	34 3	118 15	339	68
Portland	45 32	122 43	67	72	Fort Apache	33 48	109 57	5,050	54
Virginia City	45 20	112 3	5,810	52	Fort Thomas	33 4	110 2	2,710	51
Fort Bennett	44 43	100 39	1,510	69	Yuma	32 45	114 36	141	44
Deadwood	44 23	103 43	4,600	67	San Diego	32 43	117 10	67	74
Huron	44 21	98 9	1,307	71	Fort Grant	32 39	109 57	4,856	41
Boisé City	43 37	116 8	2,750	60	El Paso	31 47	106 30	3,764	48
Roseburgh	43 13	123 20	523	73	Fort Concho	31 25	100 24	1,900	64
Yankton	42 54	97 28	1,228	68	Fort Stockton	30 53	102 53	3,010	55
North Platte	41 8	100 45	2,841	65	Fort Davis	30 38	103 56	4,928	53
Cheyenne	41 8	104 48	6,105	52	Rio Grande City	26 23	98 48	230	68
Winnemucca	40 58	117 43	4,358	46	Brownsville	25 53	97 26	57	78
Salt Lake City	40 46	111 54	4,348	46					

217. (H.) When there is a second range of mountains parallel to the first, and distant from it not more than 100 or 200 miles, the influence of cause (G) is considerably intensified. This principle is exemplified in southern California, where between the Sierra Nevadas and the Coast Range of mountains the mean annual rainfall is less than 10 inches. A strong upward movement of the air at any place requires that there should be an unobstructed movement of the air from neighboring regions towards this place; and between parallel ranges of mountains separated but little from each other, this free movement of the surrounding air is impossible. This principle is illustrated by the rain map of Saxony, contained in the Saxon Jahrbuch for 1886. A reduced copy of this map is given on Plate XXXVII, Fig. 1, showing in millimetres the mean rainfall for the month of December. Along the valley of the Elbe the rainfall for December varies from 50^{mm} to 60^{mm}, while on each side of the valley the rainfall for December varies from 70^{mm} to 80^{mm}, and on the mountains it exceeds 100^{mm}. The same principle is shown with less distinctness by the smaller rivers of Saxony. The diminution of the rainfall is still more decided when the place is entirely or mostly surrounded by mountains on all sides. Spain affords an illustration of this principle. Along the west coast of the Peninsula runs a chain of mountains where the annual rainfall rises to 67 inches. Along the northern side is another range of mountains with a nearly equal rainfall. There are high mountains on the south side, and there are several interior ranges, leaving numerous intervals almost entirely shut in by mountains several thousand feet in height. The regions thus surrounded are characterized by a very small rainfall. Near the center of one of these districts is Salamanca, with an annual rainfall of about 10 inches and perhaps a little less; and there is another district about 50 miles southeast of Madrid, where the rainfall is about equally small.

The same principle will enable us to explain some of the irregularities in the distribution of rainfall over Central and Southern Europe. On the southeast side of Vienna is a district about 300 miles in diameter, which is hemmed in on all sides by mountains, some of which have great elevation. The average rainfall of this region is scarcely 20 inches, while the surrounding country has a rainfall exceeding 25 inches. The rain map of Europe affords many illustrations of the same principle; but to understand them clearly requires a familiar acquaintance with the physical features of the country.

218. (I.) Although a range of mountains 5,000 or 6,000 feet in elevation is uniformly marked by a great excess of rainfall, if the mountains rise sufficiently high there is a decrease of rainfall near the summit of the range. This is shown by Table LXXXIX, especially by the second group of stations (Nos. 3–18.) The maximum effect on rainfall in India is apparently produced at an elevation of about 4,500 feet, and before we reach a height of 10,000 feet the diminution in the rainfall is very decided. The entire number of stations as high as 10,000 feet from which we have observations of rainfall is too small for satisfactory generalization. The observations at elevated stations in other parts of the world do not apparently accord very well with those made in the vicinity of India. Table LXXXV shows that the rainfall at stations nearly 10,000 feet in height may be very great, and on Pike's Peak, with an elevation of 14,150 feet, the mean annual rainfall is 29.84 inches. These facts indicate pretty distinctly that the small rainfall at Leh (Table LXXXIX), and probably also that at Niti, is partly due to other causes than simple elevation.

219. (K.) Elevated plateaus generally have less rainfall than insulated mountain peaks of an equal elevation. The basin of the Great Salt Lake is a plateau 400 miles long and 150 miles broad, with an average elevation of nearly 5,000 feet, and a mean annual rainfall of 17 inches. This may be regarded as an example of cause (H), but I think that the elevation of the plateau contributes in a very appreciable degree to the dryness of the air and the smallness of the rainfall. A large portion of the region lying between the Rocky Mountains and the Sierra Nevadas consists of plateaus of irregular form having an elevation about the same as the Salt Lake Basin and an atmosphere about equally dry.

The interior of Mexico consists of a narrow table-land more than 6,000 feet in elevation, extending from north to south through the whole length of the Republic, and having an average rainfall of less than 25 inches, although in the vicinity of Vera Cruz the annual rainfall exceeds 100 inches. On ascending from the coast to a distance of less than 200 miles, and an elevation of from 6,000 to 8,000 feet, we pass from a rainfall of over 100 inches to a rainfall of less than 25

inches. This rapid diminution of the rainfall must be ascribed mainly to the elevation of the plateau, for on the east side (from which direction come the prevalent winds) there is no chain of mountains of sufficient height and sufficiently continuous to produce so great an effect. The air on this plateau is quite dry, especially during the month of April. This will be seen from Table XCV, which shows the mean relative humidity at six stations, each of which is elevated more than 6,000 feet above the sea.

TABLE XCV.—*Mean relative humidity in Mexico.*

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Puebla	53	52	49	44	45	58	61	70	67	57	59	51	55
Mexico	58	51	47	42	52	67	70	71	70	67	64	55	59
Guanajuato	51	53	48	37	51	54	63	66	60	66	62	56	55
Pabellon	56	50	44	33	47	58	65	72	66	67	60	53	56
Potosi	60	57	62	54	61	64	66	67	65	67	65	68	63
Zacatecas	57	54	45	30	42	58	63	73	60	65	59	51	55

Among all the plateaus of the globe, that of Tibet is the most remarkable for its extent and elevation combined. Its average elevation is 16,000 feet, and its length (with considerable variations of elevation) is about 1,200 miles, and its breadth 700 miles. On this plateau Leh is situated, with an annual rainfall of less than three inches. A portion of this effect may be ascribed to the situation of Leh on the leeward side of the Himalaya Mountains, but over the entire extent of Tibet the annual precipitation is extremely small.

The atmosphere of Leh is habitually very dry. This is shown by Table XCVI, which gives for each month the mean relative humidity, and also the mean elastic force of the aqueous vapor, expressed in inches of mercury.

TABLE XCVI.—*Relative humidity and force of vapor at Leh.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Relative humidity	59	59	54	42	38	37	45	49	43	40	50	57	48
Force of vapor	.067	.072	.094	.104	.124	.184	.259	.270	.189	.099	.081	.072	.135

Another table-land almost equally remarkable (the Punos) is found in South America, between two great chains of the Andes, and this table-land is celebrated for the dryness of its atmosphere.

Most of the countries which on Plate XXXIII are represented with a rainfall less than 10 inches, are plateaus of moderate elevation, and this elevation may have an appreciable influence upon the amount of the rainfall. The average elevation of the Sahara is over 1,500 feet, and although this is small in comparison with other plateaus which have been named, it may contribute in some degree to the smallness of the rainfall.

220. (L.) Another condition which is unfavorable to rainfall is extreme dryness of the atmosphere. This cause may be regarded as including each of the preceding cases except the first (F), but as the conditions which determined the dryness of the air in those cases were peculiar, I have thought it best to give each of them a distinct mention. The reason why a very dry condition of the atmosphere is unfavorable to rainfall is obvious. The precipitation of the vapor of the air is chiefly caused by an upward movement of the air, by which it is carried to a height where the temperature is considerably below the dew-point. When vapor is precipitated, its latent heat is liberated, by which means the neighboring air is warmed, and this develops an additional force which draws in a new supply of air. Moreover, the specific gravity of the vapor of water is only five-eighths that of dry air. Although this dry air may ascend from the earth's surface in consequence of increased heat, or from the effect of an interposed mountain, moist air has a much greater ascensional force, and the greater the amount of vapor in the air, the greater is the force resulting from the heat liberated in its condensation. In a region where the air is very dry, the rains are small and infrequent, because the ascensional force of the air is small and it derives but

little increase from the condensation of vapor. This principle applies not only to regions which are popularly called deserts, but also to those regions where the year is divided into a rainy season and a dry season, and also to those extensive droughts which occasionally occur in countries which ordinarily have a liberal supply of rain.

The droughts which prevail in California during the summer show the connection between dry air and small rainfall. During the three summer months as far north as latitude 41°, the average rainfall in California is less than two inches and with a very few exceptions it is less than one inch. This period is characterized by a very dry atmosphere at places removed a short distance from the Pacific coast. This will appear from Table XCVII, which shows for each month of the year the mean relative humidity for three stations in Arizona and two stations in California.

TABLE XCVII.—*Mean relative humidity in California and Arizona.*

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Yuma, Ariz	44.6	42.2	41.6	39.8	33.8	35.8	39.3	42.3	40 3	40.2	38.9	44.6
Fort Grant, Ariz	48.9	45.5	38.0	28.4	22.6	25.1	48.6	56.9	41.4	35.9	40.7	47.1
Prescott, Ariz	54.2	53.6	46.0	39.7	28.1	26.0	44.4	53.1	42.4	41.8	48.0	55.9
Red Bluff, Cal	50.0	45.2	43.8	42.3	39.7	37.6	36.5	35.4	42.0	46.6	50.5	52.2
Sacramento, Cal	56.3	54.4	54.6	48.0	43.4	40.7	40.7	40.5	45.2	48.2	53.1	55.1

During the three winter months the average rainfall near the California coast in latitude 41° is 30 inches; a rainfall of 20 inches extends southward to latitude 38°; and a rainfall of 10 inches extends southward to latitude 37°. Why should there be such abundant rains in winter, and no rain in summer? I think a partial answer to this question is to be found in the storms which prevail in the neighborhood of the Aleutian Islands, during the colder part of the year, and which travel eastward and make their influence felt along the Pacific coast, powerfully as far south as latitude 38° and more feebly as far as latitude 30°. The great barometric fluctuations over the Pacific Ocean almost entirely disappear during the summer months, as will be seen from Table LXIX, Chapter II, corresponding in this respect with the great storms of the Atlantic Ocean as shown by Table LVII, Chapter II. I think, however, that the habitual dryness of the air is a very important cause which renders the summers in California almost rainless, and which in winter prevents the rains of northern California from extending to southern California and Arizona; and this extreme dryness of the air in summer is largely due to the direct heating effect of the sun's rays. In summer the mean temperature of the interior of California in latitude 37° is 84° F. and in latitude 40° it is 76° F. The vapor to be precipitated comes from the Pacific Ocean, whose mean temperature in summer on this part of the coast is nearly 60°. This relatively cool air from the ocean as it advances eastward over California becomes very dry, and it requires a large reduction of temperature to condense any of its vapor. In winter the air from the ocean is a little warmer than the land, and slight causes are sufficient to condense a portion of its vapor.

221. The droughts which habitually prevail over southeastern Europe in summer afford additional information respecting the connection between dry air and small rainfall. In summer the rainfall in Sicily, southern Italy, and Greece is extremely small, and this period is characterized by northerly winds, which are uncommonly persistent. This is shown by Table XCVIII, which gives the results of 5 years' observations at Palermo in Sicily from 1875–'79. The table shows for sixteen points of the compass the average number of wind observations during each month (there being six observations daily); also the number of calms, the mean relative humidity, and the average rainfall for each month.

It will be seen that during the colder months of the year southerly winds predominate, and this is the time of greatest rainfall. During the warmer months of the year northerly winds are even more prevalent than the southerly winds were in winter, and during the 4 months from May to August the average rainfall is only 1.23 inches, which is at the rate of 3.69 inches per year. Also during the same period the mean relative humidity is only 62. We see, then, that at Palermo small rainfall is associated with the prevalence of dry northerly winds.

TABLE XCVIII.—*Winds at Palermo, Sicily.*

Months.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	Calm.	Hum.	Rain.
Jan ...	5	3	16	3	8	3	4	1	2	0	8	53	48	10	6	4	12	67	3.13
Feb ...	6	2	18	4	6	0	1	0	2	1	7	52	37	9	2	5	18	66	2.03
Mar ...	7	3	20	8	8	1	1	1	2	1	11	45	36	13	7	4	16	62	2.48
Apr ...	6	3	22	9	12	1	3	0	2	1	16	34	35	13	7	3	12	60	1.62
May...	5	3	41	18	17	2	3	2	2	1	10	32	21	10	4	2	13	61	.38
June ..	5	4	46	23	24	2	1	0	0	0	5	28	11	6	3	2	20	64	.42
July ..	4	3	55	19	20	1	0	0	0	0	9	28	17	6	4	3	16	60	.41
Aug...	5	1	48	30	24	0	0	0	0	1	12	35	9	3	1	1	14	63	.02
Sept...	6	2	38	16	18	1	0	0	0	2	13	43	20	7	3	3	7	65	2.45
Oct....	3	1	33	10	7	0	1	0	1	1	15	50	34	9	3	3	14	65	2.52
Nov ...	4	2	14	5	6	1	1	0	1	2	18	63	35	7	5	2	15	63	3.18
Dec ...	7	2	15	3	7	2	1	0	1	2	18	62	43	7	3	2	10	66	3.28

222. Under the head of dryness of the atmosphere (L), I will include three special cases which are unfavorable to rainfall, viz:

(*a*) Remoteness from the ocean, measured in the direction from which the prevalent wind proceeds. This principle has been sufficiently explained in Article 212.

(*b*) Areas of high barometric pressure. We have found in Chapter II that areas of high pressure are generally characterized by a low temperature, a calm atmosphere, a clear sky, and the absence of rain or snow. This is specially noticeable in Central Asia, where during the colder months the areas of high pressure are unusually large and persistent. During this period the amount of precipitation in the form of rain or snow is extremely small, as will be seen from Table XCIX, which shows for each month in English inches the mean amount of precipitation at four stations which are generally included within the high areas of Central Asia.

TABLE XCIX.—*Mean monthly precipitation in Asia.*

Stations.	Jan.	Feb.	Mar.	Apr.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Nertschinsk	.08	.07	.24	.47	.93	2.47	4.01	4.32	1.86	.46	.29	.18
Pekin	.10	.16	.26	.49	1.49	3.23	8.84	6.45	2.73	.74	.31	.10
Kjachta	.10	.09	.09	.05	.51	2.36	2.97	2.56	.91	.21	.18	.21
Barnaul	.26	.17	.26	.35	.99	1.26	1.53	1.62	.81	.72	.63	.45

223. (*c*) Another condition which is unfavorable to a large rainfall is high latitude. From general principles we should expect that the average rainfall would be greatest in those regions where the atmosphere contains the most vapor, and that the rainfall would diminish as the amount of vapor in the air diminishes. In warm countries the average dew-point is about 6° below the temperature of the atmosphere. The mean temperature of the equator is about 80° F. and the mean dew-point 74°, at which temperature the elastic force of aqueous vapor is 0.839 inch. In latitude 60° north the mean temperature is about 29°, and I will assume the mean dew-point at 26°, at which temperature the elastic force of aqueous vapor is 0.141 inch, which is about one-sixth of that found for the equator. If, then, the causes which affect the precipitation of the vapor of the air were the same in all latitudes, we might conclude that the rainfall at the equator would be six times as great as in latitude 60°, and that in traveling northward the average rainfall would diminish with the same regularity as the mean temperature diminishes. A glance at Plate XXXIII is sufficient to show that such a conclusion is very erroneous. Nevertheless if we determine the average rainfall for each 10° of latitude, we shall be convinced that latitude does exert an important influence on the amount of the rainfall, and this influence is most decided in very high latitudes. Table LXXXII gives the annual rainfall at four stations whose latitude exceeds 71°, and the mean of the numbers for these four stations is 7.44 inches. In the numerous Arctic expeditions which have been undertaken within the last 70 years, observations of the barometer, thermometer, wind, etc., have been made with great care, but by common consent the fall of snow has

been pronounced too small to be measured. Such estimates of the amount of snow as have occasionally been given appear to me to be consistent with the result above stated, viz, 7.44 inches mean annual precipitation.

224. (M) Another condition which is unfavorable to rainfall is the absence of tracks of barometric depression. In Article 214 I have endeavored to show that the average tracks of the great barometric depressions are marked by an excess of rainfall. If this proposition be conceded, I think it follows that the absence of such tracks must be unfavorable to rainfall. If the Aleutian Islands were situated 5° further south than they now are, I think the average storm tracks from the Pacific Ocean would meet the coast of North America further south than they now do, and this would carry the rainfall of 75 inches further south than we now find it. If any one should contend that I confound cause and effect, he must at least admit that there is an intimate connection between small rainfall and the absence of tracks of barometric depression. This must be evident from a comparison of Plate XI, Chapter I, with Plate XXXIII. It should, however, be kept in mind that Plate XI does not show the *relative frequency* of storm tracks for different parts of the northern hemisphere. These storm tracks were chiefly derived from the charts of the International Bulletin. There are certain regions where storms are passing almost unint erruptedly, and if I had attempted to represent on Plate XI *all* the storm tracks delineated on the charts of the International Bulletin, there are certain regions which would be marked by a broad belt entirely black, in which no individual storm track could be distinguished. In such regions I have represented only a few tracks as a specimen of the whole. But for those regions where storm tracks seldom occur, I have represented *every* track delineated on any of the charts of the International Bulletin, not a single one has been intentionally omitted. It will be seen that there are certain regions where not a single storm track appears on any of the charts of the International Bulletin, and there are other regions where such tracks are extremely infrequent. Among these regions we find the whole of Mexico, including Southern California and Arizona. This peculiarity is best exhibited by Plate X, which shows the storm paths of the United States on a much larger scale. There are no storm tracks throughout the whole of Africa with the exception of an occasional one in Algeria. The same is true of Arabia and southwestern Asia as far as India. All these countries are characterized by a small rainfall, generally less than 10 inches.

I concede that when a storm advances into a very dry region, the rainfall is rapidly diminished, the force which sustains the energy of the storm is impaired, and the barometric depression soon becomes too small to be followed. In such cases the absen ce of storm tracks may be said to be the *effect* of the dryness of the atmosphere. There appear however to be other cases in which storm tracks, instead of being obliterated by encountering a very dry atmosphere, are diverted to some other region where there exist special conditions favorable to a great rainfall (such as ranges of mountains, high lands or large bodies of water), and in such cases it seems proper to regard the absence of storm tracks as one of the causes of small annual rainfall. This peculiarity of the tracks of barometric minima in Europe is clearly shown by Fig. 9 of the plate accompanying the Monatliche Uebersicht of the Deutsche Seewarte for April, 1885. The southern hemisphere affords very remarkable examples of the influence of storm tracks upon the amount of rainfall. During the colder months of the year storm tracks graze the southern margin of Australia, and they are marked by a liberal rainfull, while during the warmer months of the year the storm tracks disappear, and the rain disappears also (see Article 214). A similar effect is observable in the vicinity of the Cape of Good Hope.

225. It may be claimed that if the causes here enumerated as affecting the amount of the mean annual rainfall are *veræ causæ*, and if the enumeration is complete, we should be able to explain all the peculiarities in the distribution of rainfall which are shown by Plate XXXIII. I do not claim to be able to do this. This would require a minute acquaintance with the physical peculiarities of all parts of the globe. Moreover apparent anomalies may arise from other causes. The rain map of the United States published by the Smithsonian Institution exhibits numerous anomalies, some of which may perhaps be due to errors in the observations, and others to the very short period which some of the obs rvations represent. If no observations were represented upon the map except such as embraced a period of at least ten years, and the observations were all made upon a uniform system. it is presumed that many of the anomalies now seen would disappear.

I think, however, it is possible to give a satisfactory explanation of the main features of the rain distribution in all parts of the world. I will make a general review of Plate XXXIII, beginning with the cases of unusually large rainfall and giving special attention to cases in which the rainfall amounts to 75 inches. We shall find that the chief causes of such large rainfall are mountains and proximity to the ocean. These are the principal causes of the great rainfall on the northwest coast of North America; also of the great rainfall on some of the West India Islands and on the coast of Mexico near Vera Cruz. It should, however, be borne in mind that a station near sea level may have a great rainfall, due to the influence of a neighboring range of mountains, as explained in article 211.

The great rainfall on the east coats of Central America is to be ascribed to the same causes, and the extension of this heavy rainfall to a small portion of the Pacific coast of South America north of the equator is to be ascribed to the southwest winds which there prevail, and which constitute monsoons on a small scale and produce effects similar to the southwest monsoons of India.

The irregularity in the distribution of rainfall along the Atlantic coast of South America presents some difficulties, but I think these irregularities are chiefly due to the presence or absence of mountain ranges near the coast, and to the greater or less freedom of exposure to the northeast and southeast trade winds.

226. Table LXXXII contains one example of great rainfall (No. 425, at San Luis de Maranhão, latitude 2° 31′ south) which seems inconsistent with the general character of the observations along the neighboring coast, and I conclude that the observations are untrustworthy or that they represent a year which was quite exceptional. In order to obtain some light on this question I wrote to Prof. Orville A. Derby, of Rio de Janeiro, Brazil, and the following is a portion of his reply:

> I have not been able to obtain any definite information regarding Maranhão except that it is not generally regarded as an exceptionally rainy place. I know no reason why it should differ so materially from Ceará and Pará. In the province of Ceará the year 1819 was one of floods, and 1824–'25 was one of drought comparable with that of 1877–'79, but there is no record of the character of the intervening years. The year 1866, the heaviest recorded flood year in Ceará, had less than half the rain recorded for 1821 in Maranhão, and only 300^{mm} more than the single month of April. The rainiest month was May, with 660^{mm} in 20 days, or less than that of the single storm of April 4–6, 1821, the greater part of which fell in two periods of 8 hours each. The regularity of the barometer also appears to me suspicious at a time of such extraordinary tempest, and I am inclined to think that the instruments were badly disposed or the observations were carelessly made.

The following is a summary of the rainfall observations for the year 1821 at San Luis de Maranhão, by Antonio Bernardino Pereira Lago:

January	1 ft.	3 in.	3.6″	June	0 ft.	4 in.	2.4″	November	0 ft.	1 in.	9.3″
February	4	5	3.8	July	0	4	1.9	December	0	4	10.5
March	6	5	0.0	August	0	0	.0				
April	6	11	11.1	September	0	0	.0	Year	23	5	2.7
May	3	0	8.1	October	0	0	.0				

227. The comparatively small rainfall on the flanks of the Andes south of latitude 11° south may be ascribed to distance from the ocean and the precipitation of the vapor of the air in passing over the numerous mountain ranges of Brazil. The same consideration would lead us to conclude that the great rainfall (91.26 inches) observed at San Antonio (No. 432) in 1873 does not fairly represent the average rainfall of that region. The great rainfall on the western coast of South America south of latitude 36° south is due to the same causes as that on the northwest coast of North America. This review makes it quite apparent that we need many more observations from South America before we can draw the lines of equal rainfall with confidence.

Turning now to the continent of Europe we find a most intimate connection between great rainfall and mountain ranges, and in the northern part of the continent the effect of proximity to the ocean is distinctly marked. The mountains of Norway, those on the western coast of Great Britain and Ireland, and those on the borders of Spain and Portugal afford illustrations of these principles.

The Alps throughout their whole extent are marked by a heavy rainfall, and several smaller mountains in Germany are similarly marked. Genoa shows a large rainfall, due to the high hills in its vicinity, and the same is true of Fiume and Ragusa, on the Adriatic. The Caucasus Mountains are marked by a heavy rainfall, which forms a strong contrast with the desert region in the immediate neighborhood. The great rainfall in southern and southeastern Asia has already been sufficiently explained. The great rainfall on the islands of the East Indian Archipelago is due to the mountainous character of those islands, and to their situation near the center of the great equatorial rainbelt. The great rainfall at some places on the western coast of Africa a little north of the equator is due to the southwest winds which there prevail, producing effects similar to the southwest monsoon of India.

228. If we make a similar review of all the regions which show a very small rainfall we may have more difficulty in assigning explanations which will be accepted without protest. I will, however, make the attempt, and will begin with the Sahara, since this is a case which presents peculiar difficulties. It is important at the outset to obtain as definite information as possible respecting the meteorological conditions of this region, including the pressure, temperature, and humidity of the air, the direction and force of the winds, etc. Unfortunately the observations which we have from the interior of the Sahara are few and fragmentary, yet I think they are sufficient to afford an explanation of the main features of this desert. The most satisfactory observations which I have seen from the Sahara and the Soudan are those made by Gerhard Rohlfs in the years 1865–'67, and published in Petermann's Mittheilungen, Ergänzungsheft No. 34. Table C contains a summary of the wind observations and the relative humidity of the air at four stations where the expedition spent most of its time. The summary was prepared by Dr. J. Hann.

TABLE C.—*Meteorological observations in Africa, by Gerhard Rohlfs.*

	Frequency of winds, per cent.									Relative humidity.				
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Sunrise.	9 a. m.	3 p. m.	Sunset.	Mean.
1. Ghadames: Lat. 30° 10′ N., long. 9° 3′ E.; elevation 1,283 feet.														
1865. July	6	21	6	9	4	1	2	7	44	36	26	19	26	27.5
August	4	11	15	5	5	0	1	3	56	41	.....	25	33	33.0
2. Mursuk: Lat. 25° 54′ N., long. 14° 10′ E.; elevation 1,650 feet.														
1865. October	12	3	12	10	23	8	5	4	23	.....	.....	.....	.....	.....
November	12	12	3	4	3	3	6	6	51	58	47	35	51	47.7
December	14	4	6	0	2	5	19	11	39	67	54	38	47	51.5
1866. January	7	5	5	1	2	2	11	14	54	62	55	33	60	52.5
February	5	1	4	3	3	8	12	7	57	44	35	24	41	36.0
March	3	3	10	3	11	7	8	3	52	46	28	21	32	31.7
3. Schimmedru: Lat. 18° 57′ N., long. 13° 17′ E.; elevation 1,624 feet.														
1866. April	20	8	8	7	14	1	0	5	37	.....	.....	.....	.....	.....
May	3	2	8	4	16	2	2	1	62	.....	.....	.....	.....	.....
June	5	5	13	12	10	3	2	3	47	36	32	23	23	28.5
4. Kuka: Lat. 12° 52′ N., long. 13° 24′ E.; elevation 1,168 feet.														
1866. July	2	1	1	1	8	31	10	0	46	.....	.....	.....	.....	.....
August	0	2	0	2	2	18	10	0	66	95	85	66	90	84.0
September	1	2	8	19	5	6	4	4	51	.....	.....	.....	.....	.....
October	15	15	6	5	0	1	0	1	57	77	47	35	59	54.5
November	10	7	31	0	0	0	0	0	52	64	39	31	49	45.7
December	12	26	3	0	0	0	0	11	48	.....	.....	.....	.....	.....

The observations for October, 1865, were made during the journey from Ghadames to Mursuk; and those for April 1866, were made during the journey from Mursuk to Schimmedru. Ghadames is near the northern margin of the Sahara, and Kuka is a little south of its southern margin The following are some of the conclusions which may be drawn from these observations:

1. Within the Sahara the air is entirely calm *more than half the time.* The average of the calms for the first three stations in the table is 47.5 per cent. The observations were made four times a day, viz: sunrise, 9 a. m., 3 p. m., and sunset. At sunrise and sunset the calms amounted to 66 per cent. of the whole number of observations at those hours; that is, the winds generally subside at sunset and do not commence blowing again until after sunrise. During the entire 24 hours the percentage of calms is considerably more than 50.

2. At all of the stations northerly winds predominate very decidedly in winter, and at Ghadames they predominate in summer. Southerly winds predominate at Schimmedru and Kuka in summer.

3. At Ghadames and Schimmedru the average humidity of the air in summer is 29.7 per cent. and in winter it is 46.7 per cent. at Mursuk.

4. At Kuka there is a liberal rainfall annually; but at the other three stations the total annual rainfall is very small. During a residence of two months at Ghadames, Rholfs saw a little rain in one instance, and a few drops in two other instances. During a residence of six months at Mursuk, it rained ten times, most of the rains being slight. During three months' residence in Schimmedru and its vicin ity, three slight rains occurred. These rains in the desert of Sahara are generally of short duration and of small geographical extent.

229. The cause of the rainless character of the Sahara does not appear to be precisely the same in summer as in winter. I will therefore consider the two seasons separately, and will begin with winter. In winter the northern margin of the equatorial rain belt retreats almost to the equator, so that with slight exceptions the whole of Africa from the parallel of 30° down almost to the equator is well-nigh rainless. Throughout this whole region the distribution of atmospheric pressure, temperature, and humidity are such as to cause a prevalence of northerly winds. From latitude 30° to the equator the average pressure diminishes somewhat over a quarter of an inch, which gives an average gradient of about 0.01 inch for each degree of latitude. The temperature increases by more than 30°, and the humidity of the air also increases. These causes are sufficient to determine a prevalent wind from the north, and all the observations that we have from this region fully confirm this conclusion. These northerly winds in their progress towards the equator are continually advancing into a warmer region, that is, they are becoming dryer, and this is a condition unfavorable to rainfall. Occasionally a shower of considerable violence, but of small extent, falls in the middle of the Sahara. Such a shower may result from the influence of some local cause; but the shower does not long continue, and it does not increase in extent, because the distribution of pressure above described does not favor the diversion of the air from its prevalent direction, so as to form a cyclonic system; and the small amount of vapor in the air does not supply the force requisite to sustain a continued cyclonic movement.

The authority for the preceding statements with regard to rainfall, especially for the interior of the continent, is derived from the observations of scientific travelers, who however have seldom attempted to measure the amount of the rain in a gauge, but have contented themselves with recording the number of rains or showers. Table CI shows the monthly rainfall for six stations, most of which are situated on the coast.

TABLE CI.—*Monthly rainfall in Africa.*

	Lat.	Long.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° ′	° ′												
Alexandria	31 12	29 52 E	2.13	1.57	1.30	0.12	0	0	0	0	0.04	0.51	1.50	1.53
St. Louis, Seneg..	16 1	16 30W	0.28	0.12	0	0	0.04	0.55	2.17	9.68	2.99	0.20	0.04	0
Goree, C. Verde ..	14 40	17 25W	0	0.08	0	0	0	0.83	4.05	10.94	4.65	0.28	0.12	0
Gondar, Abis.....	12 36	37 31 E	.....	.....	.....	.....	.....	.....	11.97	15.67	4.25	3.62	1.10	.....
Freetown	8 29	13 9W	0.69	0.31	0.52	3.97	2.38	12.91	24.21	25.83	29.17	12.48	3.57	1.61
Elmina	5 5	1 20W	0·04	1.93	1.89	3.23	7.40	6.73	1.69	1.06	0.91	2.36	2.13	1.42

In summer the distribution of temperature and pressure over Africa are very different from what they are in winter. In summer the highest temperature is found near the parallel of 20° north, and here the mean temperature is about 100° F. or 20° greater than it is on the equator. The result of this intense heat is that the air is expanded; it swells up and flows off to other parts of the globe, leaving a diminished pressure over the region of greatest heat. Thus in summer, over northern Africa, there is a permanent area of moderately low pressure, whose center is near latitude 17° north, and here the mean pressure is about a quarter of an inch less than it is at the equator. This distribution of temperature and pressure determine the direction of the prevalent winds. In northern Africa, down to near the parallel of 17°, northerly winds prevail, and they generally have an inclination to the northeast. Between the parallel of 17° and the equator, southerly winds generally prevail. The rainfall is intimately connected with the direction of the prevalent wind. In northern Africa, where northerly winds prevail, the atmosphere advances from a cooler to a warmer region; that is, it is continually becoming dryer, and this condition is unfavorable to rainfall. The southerly winds which prevail from latitude 17° to the equator also advance from a cooler to a warmer region, which is a condition unfavorable to rainfall. But this cause is counteracted by a much more powerful influence. The great equatorial rain belt, which is the result, not of local causes, but of causes which depend upon the general circulation of the atmosphere for the entire globe, advances in summer into the northern hemisphere, and the resulting rains sometimes extend northward to latitude 17°. These statements are illustrated by Table CI. Thus in summer the rains of Africa extend from the equator to near the parallel of 17° north; but north of this line the entire continent is well-nigh rainless. The result for the entire year is that there is an extensive region where the mean annual rainfall is less than 10 inches. The boundaries of this region are somewhat irregular; but the southern boundary is near the parallel of 17° latitude, and the northern boundary is somewhat north of the parallel of 30°. This explanation is applicable to all that part of northern Africa which, on Plate XXXIII, is represented as having a rainfall less than 10 inches.

230. The preceding results will enable us to understand more clearly the cause of the droughts which prevail in summer over southeastern Europe, as shown by the record at Palmero, article 221. In summer northerly winds prevail not only over the whole of northern Africa, but they extend into southern Italy and Greece, and throughout all this region the rainfall in summer is extremely small.

A similar explanation is applicable to the region of small rainfall in Arabia. During winter, the mean temperature of northern Arabia is about 56° F., while at the equator it is about 80° F. The mean pressure in northern Arabia is a quarter inch greater than it is at the equator. Hence in winter northerly winds should prevail in Arabia, which conclusion is confirmed by the observations, and the general result is the same as in northern Africa, viz, an almost entire absence of rain.

In summer a mean temperature of 90° F. prevails in central Arabia, while at the equator the mean temperature scarcely rises to 80°. The mean pressure diminishes from the equator northward to central Arabia. Hence in Arabia southerly winds should prevail to about latitude 20°, and north of this parallel northerly winds should prevail. These conditions are similar to those which we have found for the Sahara. The elevation of the country above the sea contributes to the small rainfall in Arabia, it being a plateau of from 3,000 to 5,000 feet in elevation.

Similar conditions prevail throughout the region of small rainfall in Persia and Beluchistan, this region forming a plateau with an elevation of from 4,000 to 6,000 feet. Between this region and Arabia the annual rainfall is a little more than 10 inches. This increased rainfall is probably due, at least in part, to the small elevation of the country above the sea. At Bushire on the Persian Gulf, in latitude 29°, the mean annual rainfall is 14.50 inches, all which falls from November to April, and nearly all of it falls during the three winter months when southeast winds frequently alternate with northwest winds.

231. The desert character of Thibet is due to its position on the leeward side of the Himalaya Mountains, but the effect is greatly intensified by the extreme elevation of this plateau. The desert character of Gobi is due partly to the fact that the prevalent winds come from a desert region; partly to the elevation of the plateau, which is about 4,000 feet; and partly to an extensive range of mountains on its southeast side which shut off the vapor which otherwise might come from the Pacific Ocean.

The small rainfall in the vicinity of the Caspian and Aral Seas is due partly to position in the interior of a vast continent. We have found in article 212 that the mean annual rainfall in the eastern part of European Russia is about 14 inches. In the vicinity of the sea of Aral this amount is further diminished by the northerly winds which generally prevail in that region at all seasons of the year. Table CII shows for each month the character of the winds at Irgis, a station north of the sea of Aral. The table shows the number of times (in a hundred observations) that the winds blow from the eight principal points of the compass, and also the number of calms derived from five years' observations 1880–'84.

TABLE CII.—*Winds at Irgis, Asia, Lat.* 48° 37′ *N., Long.* 61° 16′ *E.*

Points.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
North	11	11	14	17	14	15	17	14	15	10	12	7
Northeast	5	6	8	18	8	10	8	7	5	2	2	10
East	5	4	6	15	13	8	5	6	5	3	4	6
Southeast	1	1	1	1	4	3	0	2	2	2	3	2
South	9	4	3	4	5	6	5	5	6	8	8	11
Southwest	9	9	12	4	4	5	7	5	8	9	6	7
West	18	21	13	9	10	18	19	13	18	19	18	13
Northwest	5	12	9	7	10	10	11	12	10	10	7	8
Calm	37	32	34	25	32	25	28	36	31	37	40	36

We see that for each month northerly winds are more frequent than southerly winds, but the difference is greatest during the eight months from February to September.

In the extreme northern part of Asia is another area having less than 10 inches rainfall, which is apparently the result of high latitude and distance from the ocean, measured in the direction of the prevalent winds. There is a similar area in the northern part of North America which is probably due to the same cause.

232. In northern California and Arizona is a region of considerable extent which is well-nigh rainless. We have seen in article 220 that the dryness of the air in this region is nearly if not quite equal to that of the Sahara. Table CIII shows the number of times (in a hundred observations) that the wind at Yuma blows from the eight principal points of the compass, and also the number of calms as deduced from the observations of 4½ years (three times a day), 1880–'84.

TABLE CIII.—*Winds at Yuma, Arizona, Lat.* 32° 43′ *N., Long.* 114° 36′ *W.*

Month.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Mean Direction.	Rain.
										°	
January	32	20	4	8	5	4	4	13	10	N. 10 E.	0.43
February	21	16	4	8	5	10	11	18	7	N. 20 W.	0.52
March	14	7	4	8	12	14	13	16	12	N. 79 W.	0.08
April	7	6	4	9	11	20	18	17	8	S. 74 W.	0.09
May	7	6	4	13	14	17	12	19	8	S. 61 W.	0.01
June	2	6	5	18	9	24	15	9	12	S. 31 W.	0.01
July	2	5	5	25	21	21	7	4	10	S. 3 E.	0.22
August	4	6	5	25	15	21	5	6	13	S. 5 E.	0.25
September	6	14	6	10	9	18	9	11	17	S. 54 W.	0.09
October	12	21	5	7	3	13	10	15	14	N. 15 W.	0.04
November	26	28	3	2	2	8	5	13	13	N. 6 E.	0.03
December	28	26	4	5	3	4	6	15	9	N. 8 E.	0.31

In winter the mean temperature of Yuma is 56° F., which is 24° colder than it is at the equator, and the mean pressure is 0.3 inch greater than it is at the equator. These two causes should determine a prevalent wind from the north, which accords with the results of Table CIII. The wind blowing from a colder to a warmer region is continually becoming drier, and this is unfavorable to rainfall. It is true that at the same time heavy rain is falling in northern California, but this is due largely to the violent storms which prevail in the North Pacific Ocean, and whose influence is felt along the American coast from latitude 60° to latitude 40°; but this influence is seldom felt as far south as Yuma.

In summer the lowest pressure in North America is found in the Salt Lake Basin, and the highest temperature (90° F.) is found in Arizona, and the center of this heated region is northeast of Yuma. These causes determine southerly winds (generally southwesterly winds) at Yuma. which accords with the observations in Table CIII. Since these winds tend towards a region which is excessively dry, little rainfall can be expected.

233. Some may be surprised that the winds at Yuma do not bear a more decided resemblance to the trade winds, and may suggest that over Arizona there may be a stratum of air a little elevated above the earth where the northeast trade winds prevail. In order to obtain information on this point I have prepared Table CIV, which shows the number of times that the clouds (both upper and lower) were observed to come from the different points of the compass, as deduced from the international observations made once a day for three years, 1881–'83.

These observations do not show a single month in which the prevalent direction of either the upper or lower clouds was from the northeast. We thus find very little trace of the regular trade winds in the upper or lower strata of the atmosphere over Arizona.

234. The principal desert in the Southern Hemisphere is in Australia. During the colder months of the year an area of moderately high pressure prevails very persistently over Australia, and the mean temperature of the land is lower than that of the surrounding ocean in the same latitude. There is therefore a general tendency of the winds outward from the interior of the continent. We have found, article 221, that such a condition of things is unfavorable to rainfall, and (with the

TABLE CIV.—*Movement of the clouds at Yuma, Ariz.*

Months.	Upper clouds.								Lower clouds.							
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
January	....	....	....	....	....	2	1	....	2	....	....	2	1	2	....	2
February	....	....	....	....	1	4	1	....	1	2	1	2	4	2	1	1
March	....	....	....	....	3	....	3	....	....	....	2	...	....	2	2	2
April	....	....	....	1	....	3	1	....	....	....	....	....	....	3	....	1
May	1	....	1	1	....	4	2	1	....	....	....	2	1	1	....	2
June	....	....	....	1	....	2	....	1	1	....	....	5	1	....	....	....
July	....	2	3	4	....	....	3	1	....	2	9	8	2	....	....	....
August	....	....	....	7	....	1	....	....	1	2	4	15	1	....	....	1
September	....	....	....	2	....	....	....	....	....	1	2	3	....	2	1	1
October	....	....	....	....	....	....	1	....	....	....	....	1	1	1	3	2
November	....	1	....	....	1	2	3	....	4	....	....	....	2	2	4	6
December	....	....	....	1	....	3	1	1	2	....	....	....	....	3	1	2

exception of the southern and eastern margins of the continents where other causes operate) the rainfall of Australia during this period is extremely small. Along the eastern margin of the continent the rainfall appears to be largely due to the southeast trade winds encountering the coast range of mountains, and here the rainfall is pretty equally distributed throughout the year. The southern margin of Australia is situated near the line which separates the prevalent easterly winds from the prevalent westerly winds; and here during the colder months cyclonic storms of considerable violence frequently occur, accompanied by a liberal rainfall, which sometimes extends northward beyond latitude 30°. Hence the northern portion of Australia has a liberal rainfall during the coldest months. Table CV shows the mean rainfall for each month of the year at five stations, of which the first is situated near the northern margin of Australia, and the last is near the southern margin.

TABLE CV.—*Mean monthly rainfall for Australia.*

Stations.	Lat.	Long.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° ′	° ′												
Palmerston	12 16	130 52	15.06	11.84	12.03	4.50	0.89	0.02	0.01	0.25	0.22	2.66	3.87	11.17
Powell Creek	18 6	.....	4.93	5.80	3.87	1.03	0.37	0.02	0.37	0.02	0.40	0.72	0.57	1.63
Alice Springs	23 38	133 37	2.92	2.28	1.51	0.61	0.71	0.50	0.55	0.83	0.79	0.83	0.90	0.40
Strangway's Springs	29 11	136 33	0.75	0.32	1.12	0.58	0.38	0.46	0.12	0.14	0.65	0.33	0.20	0.08
C. Northumberland.	38 5	140 40	0.84	0.91	1.20	2.22	3.66	4.25	3.57	3.95	2.87	2.06	1.70	1.22

During the warmer months of the year the interior of Australia is extremely hot, and an area of moderately low pressure prevails over it very persistently. The result is that the prevalent winds tend inward towards the central portions of the continent. These conditions are similar to those which prevail over the Sahara during the hottest months, and are unfavorable to rainfall. There is therefore little rainfall over large portions of Australia during this period. Another and more powerful cause, however, operates over the northern portion of the continent. The great equatorial rain belt is now almost entirely south of the equator, and overlaps the northern portion of Australia. In this region the rains during this period are most abundant, as is shown by Table CV, and this influence extends in a diminished degree down to the center of Australia. The result for the entire year is that there is a very liberal rainfall along the northern margin of Australia, a less liberal rainfall along the southern margin, and a very liberal rainfall along the eastern margin, while throughout the interior of the continent the mean annual rainfall is less than 10 inches.

In order to learn the character of the winds in the interior of Australia, I have prepared Table CVI, which shows how many times (in 100 observations) the wind blows from the sixteen principal points of the compass, as deduced from three years' observations (1880-'82), at Alice Springs, a station near the center of the continent.

TABLE CVI.—*Winds at Alice Springs, Australia.*

Months.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	Calm.
January	....	1	2	1	3	.....	50	.....	2	.....	4	.....	....	.....	7	1	29
February	....	.....	2	.....	4	.....	60	.....	....	.....	4	.....	....	.....	.....	.....	30
March	....	.....	2	.....	2	1	54	.....	1	.....	1	.....	....	.....	.....	.....	39
April	1	.....	1	.....	1	.....	47	.....	1	.....	2	.....	....	.....	2	.....	45
May	1	.....	2	.....	1	.....	36	.....	....	.....	2	.....	1	.....	7	.....	50
June	....	.....	....	.....	....	.....	48	.....	....	.....	1	.....	....	.....	3	.....	48
July	....	.....	....	.....	1	.....	44	.....	....	.....	.....	.....	....	.....	4	.....	51
August	1	.....	3	.....	1	.....	27	.....	....	.....	2	.....	....	.....	4	.....	62
September	1	.....	2	.....	....	1	39	.....	1	.....	1	.....	1	.....	7	.....	47
October	1	.....	3	.....	2	1	36	.....	2	.....	2	.....	1	.....	12	.....	40
November	2	.....	5	.....	3	.....	33	.....	2	.....	1	.....	....	.....	6	.....	48
December	2	.....	2	.....	2	.....	47	1	1	.....	1	.....	....	.....	5	.....	39

The number of calms for the entire year amounts on an average to 44 per cent. of the entire number of observations, which is almost as great as we have found for the interior of the Sahara. The remarkable prevalence of southeast winds is due to the fact that during the colder months of the year the center of the area of high pressure is somewhat south of Alice Springs, which gives a southerly wind at that station, and by the rotation of the earth this is converted into a southeast wind. During the hotter months of the year the greatest heat is north of Alice Springs, which also gives a southerly wind at that station. Thus southeast winds prevail almost continuously, amounting for the entire year to more than three-fourths of all the winds.

235. In Africa, south of the equator, there is a small region where the mean annual rainfall is less than 10 inches. In order to investigate the cause of this small rainfall, we must examine the distribution of temperature and pressure for the different seasons of the year. During the winter months the equatorial rain-belt passes into the northern hemisphere, and south of the parallel of 5° south latitude (with the exception of a small region about the Cape of Good Hope) the rainfall of Africa is extremely small. This appears to result mainly from the average distribution of temperature and pressure. An area of moderately high pressure prevails over this part of the continent, and the temperature is lower than that of the adjoining ocean. These conditions are similar to what we have found for Australia, and the results are similar, as will be seen from Table CVII, which gives for six stations the mean rainfall for each month of the year. The region about the Cape of Good Hope has a liberal rainfall during the colder months, for the same reason as prevails along the southern margin of Australia.

During the warmer months of the year an area of moderately low pressure prevails over the whole of Africa south of the equator, and this causes a general tendency of the winds inwards towards the center of the continent. Such a condition of things is unfavorable to rainfall. Under

the operation of general causes the great equatorial rain belt, however, advances southward and brings a liberal rainfall to most places as far south as latitude 18° south. Moreover the southeast trade winds, encountering the coast range of mountains, bring a liberal supply of rain to the eastern coast of Africa. The only portion of Africa south of the equator which does not receive rain is the southwest corner; and since (with the exception of the region near the Cape of Good Hope) this district receives little rain in winter, the mean annual rainfall is small, and the country is little better than a desert. The preceding statements are illustrated by Table CVII.

TABLE CVII.—*Monthly rainfall in Africa south of the equator.*

	Lat.	Long.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° ′	° ′												
Chincoxo	5 9	12 3	12.24	4.72	7.28	4.02	2.17	0	0	0.20	0.31	0.90	8.74	2.05
Tete	16 10	33 30	7.80	3.86	7.80	1.26	0.51	0.47	0	0	0	0	4.53	7.32
Pretoria	25 45	28 50	6.06	4.27	2.95	0.16	1.61	0	0.71	0.31	1.34	1.42	1.38	3.39
Concordia	29 35	17 57	0.04	0.20	0.39	0.59	1.34	1.93	1.53	2.44	0.87	0.16	0.20	0.08
Brakfontein	31 40	23 0	1.46	1.46	2.03	0.56	1.02	0.37	0.33	0.11	0.49	0.44	1.32	0.83
Bishop's Court	33 59	18 27	0.95	1.59	1.30	3.02	8.42	10.07	7.00	7.34	5.21	3.86	2.32	2.47

236. In the southwestern part of South America there are three stations having a rainfall less than 10 inches. These cases may be similar to that of Salamanca in Spain, Article 217. They have the Andes close upon their western side, and there are minor ranges of mountains which partly shield them on the eastern side. Their elevations range from 2,172 feet to 2,644 feet.

There is one other station in South America, Cumana, No. 411, where the annual rainfall is commonly stated at 7.52 inches. This result depends upon the observations of Humboldt, made in 1799, and the rain which he reports all fell in 2 months, September and October. If we suppose that the rainfall of these 2 months bears the same ratio to the fall for the entire year as it does at neighboring stations on each side of Cumana, we shall find an annual rainfall of 19 inches as I have given in the table. I think that 1799 must have been an exceptional year, and that the mean annual rainfall at Cumana is greater than 19 inches.

Examination of individual cases of rainfall.

237. The preceding examination of the mean annual rainfall for the different countries of the globe has developed several general principles with regard to the cause of rainfall, which are of great importance and which must operate in each individual case of rain. But there are causes operating in individual cases which do not distinctly appear in the aggregate rainfall for a series of years. For the purpose of discovering what the laws are which prevail in individual cases of rainfall, I have made extensive comparisons of all the tridaily observations of the United States Signal Service which have hitherto been published. These observations embrace a period of 41 months, viz, from September, 1872, to January, 1875, inclusive, and from January to December, 1877. I first examined the cases in which a very large rainfall (including melted snow) occurred at any station. In the southern part of the United States a rainfall of 2 inches in 8 hours occurs about twice as frequently as it does in the northern part, and in the former region these heavy rains exhibit some peculiarities which are not generally exhibited in the latter region. It is therefore convenient to exhibit the cases in two distinct tables, and for the dividing line I have adopted the parallel of 36°. For stations north of this line, I have selected all the cases in which there occurred a rainfall of 2 inches in 8 hours; and for stations south of this line, I have taken only cases in which there occurred a rainfall of 2½ inches in 8 hours. Table CVIII shows all the cases in which a rainfall of at least 2 inches in 8 hours occurred during the 41 months of observations, at any station east of the Rocky Mountains and north of the parallel of 36°, including the Canadian stations reporting to the Signal Service.

Column 1 contains the number of reference; column 2 shows the day and hour of observation (the numeral 1 denotes the 7.35 a. m. observation, the numeral 2 denotes the 4.35 p. m. observation, and 3 denotes 11 p. m.); column 3 shows the station at which the greatest rainfall was ob-

served; column 4 shows the amount of the rainfall in English inches at the given station; column 5 shows the height of the barometer at the same station; column 6 shows the direction and force of the wind at the last *preceding* observation; column 7 shows the direction and force of the wind at the date given in column 2; column 8 shows the direction and force of the wind at the next *subsequent* observation; and column 9 shows the direction of the rain center from the nearest center of low pressure. Generally there was a center of low pressure (at least as low as 29.70) within a distance less than 500 miles, with which the rainfall appeared to be intimately connected. Occasionally the nearest considerable center of barometric depression was distant more than 500 miles, and in these cases the rainfall generally appeared to be connected with a local disturbance of small geographical extent, and with small depression of the barometer. An asterisk (*) in column 9 signifies that the station of greatest rainfall was also the station of greatest barometric depression, it being understood that in some cases the rainfall is associated with a slight local disturbance, although there may have been a much greater depression of the barometer at a distance of 500 miles or more. Column 10 shows the distance (in miles) of the rain center from the center of low pressure, and column 11 shows the height of the barometer at the center of low pressure.

TABLE CVIII.—*Rainfall of 2 inches in 8 hours at stations north of latitude* 36°, *United States.*

No.	Date.	Station.	Rain.	Barom.	Direction and velocity of the wind.			Rain center from low.		Low barom.
					Prev. obs.	At date.	Sub. obs.	Direction.	Dist.	
	1872.		*Inches.*					°		
1	Sept. 23.2	Grand Haven	2.89	29.77	SE. 6	SE. 7	SE. 22	S. 84 E.	660	29.35
2	26.2	Mount Washington	2.27	30.14	SW. 43	SW. 32	SW. 20	South.	156	.93
3	28.3	Chicago	2.02	29.35	NE. 22	NE. 11	W. 16	*	00	.35
4	Oct. 25.1	Norfolk	3.41	29.95	E. 13	SE. 8	S. 20	*	00	.95
5	26.1	Philadelphia	2.09	29.78	E. 20	SW. 12	W. 8	S. 66 E.	147	.74
6	Nov. 7.1	New York	2.50	29.68	SE. 4	NW. 10	SW. 12	S. 66 W.	104	.64
7	Dec. 26.1	Norfolk	2.08	29.46	NE. 21	N. 20	NW. 12	*	00	.46
	1873.									
8	Jan. 5.2	Philadelphia	2.18	29.61	NE. 20	NE. 8	SW. 19	S. 47 E.	260	.45
9	May 1.1	Nashville	2.20	29.73	SE. 4	E. 25	S. 12	S. 61 E.	409	.58
10	9.2	New London	2.35	30.06	NE. 4	NE. 26	NE. 16	N. 42 E.	223	.95
11	22.1	Lynchburgh	2.10	30.00	NE. 4	Calm.	NE. 8	*	00	30.00
12	June 9.3	St. Louis	2.93	29.87	S. 8	S. 5	Calm.	S. 25 W.	387	29.70
13	22.3	St. Paul	2.28	29.55	SE. 13	SE. 18	SW. 2	N. 49 E.	296	.43
14	23.1	St. Paul	2.30	29.57	SE. 18	SW. 2	W. 4	N. 25 E.	195	.52
15	July 2.1	Indianapolis	2.04	29.94	SE. 12	SW. 3	SW. 8	S. 7 E.	218	.77
16	16.1	Marquette	2.10	29.94	Calm.	S. 8	S. 16	N. 88 E.	409	.47
17	16.2	Fort Garry	2.45	29.49	E. 10	S. 5	SE. 7	*	00	.49
18	17.3	Buffalo	2.00	29.64	SW. 14	SW. 7	SW. 12	*	00	.64
19	26.1	Buffalo	2.20	29.83	SE. 4	Calm.	W. 4	N. 60 E.	168	.81
20	July 27.2	Washington	2.12	30.11	S. 10	W. 8	NE. 4	S. 55 E.	175	30.04
21	27.3	Philadelphia	2.03	30.16	NW. 8	S. 8	SE. 1	S. 71 E.	362	.03
22	Aug. 13.1	Philadelphia	2.31	30.04	E. 16	NE. 12	NE. 22	N. 49 E.	250	29.92
23	13.2	Philadelphia	2.17	29.97	NE. 12	NE. 22	NE. 21	N. 49 E.	250	.85
24	13.3	Baltimore	3.26	29.86	NE. 12	NE. 12	NE. 8	N. 48 E.	40	.84
25	14.1	Breckenridge	2.05	29.86	S. 16	SE. 16	SE. 7	N. 58 E.	215	.70
26	25.2	Erie	2.00	29.82	SE. 1	W. 4	SW. 5	N. 15 W.	317	.70
27	Sept. 10.1	Norfolk	2.05	30.16	Calm.	E. 4	E. 8	N. 23 E.	655	.97
28	19.3	Mount Washington	2.20	29.86	SW. 24	W. 12	NW. 45	N. 15 W.	130	.59
29	Oct. 7.1	Portland Me	2.02	29.40	N. 12	N. 20	N. 12	*	00	.40
30	19.3	New London	2.25	29.80	SE. 2	SE. 24	SE. 32	N. 35 E.	370	.52
31	Nov. 24.2	New London	2.80	29.30	SE. 14	N. 12	NW. 6	S. 41 W.	118	.27
32	Dec. 3.2	Indianapolis	2.32	29.45	S. 16	SE. 15	S. 17	S. 33 E.	180	.37
33	3.3	Louisville	2.30	29.55	SE. 16	SE. 8	S. 12	S. 8 E.	523	.08
34	19.3	Montreal	2.12	29.78	NE. 8	NE. 7	W. 2	N. 35 W.	275	.65
	1874.									
35	Feb. 22.1	Nashville	2.10	30.00	NW. 4	W. 4	Calm.	*	00	30.00
36	Mar. 4.2	Eastport	2.08	29.39	S. 28	S. 20	S. 4	N. 62 E.	176	29.35
37	May 2.2	Fort Sully	2.40	29.74	E. 28	N. 18	N. 18	N. 34 W.	441	.17
38	24.1	Davenport	2.11	29.68	S. 12	S. 12	SW. 12	S. 78 E.	424	.52
39	June 5.1	Keokuk	2.06	29.80	S. 5	SE. 4	Calm.	*	00	.80
40	6.2	Cape May	2.08	29.94	S. 4	S. 10	SE. 6	*	00	.94
41	18.1	Mount Washington	2.10	29.88	W. 24	NW. 45	NW. 60	N. 47 W.	95	.50
42	July 4.2	Oswego	2.59	29.70	SE. 9	SE. 8	NE. 4	N. 40 E.	268	.63
43	9.1	Leavenworth	2.10	29.76	SE. 4	S. 2	N. 8	*	00	.76

TABLE CVIII.—*Rainfall of 2 inches in 8 hours at stations north of latitude 36°, etc.*—Continued.

No.	Date.	Station.	Rain.	Barom.	Direction and velocity of the wind.			Rain center from low.		Low barom.
					Prev. obs.	At date.	Sub. obs.	Direction.	Dist.	
	1874.		*Inches.*					°		
44	July 25.1	Grand Haven	2.40	29.73	Calm.	SE. 15	S. 13	S. 63 E.	351	29.42
45	26.3	Pittsburgh	2.08	29.85	S. 8	SW. 12	W. 4	S. 19 E.	112	.79
46	Aug. 8.1	New London	4.45	29.88	SW. 13	SW. 20	SE. 8	S. 40 E.	128	.76
47	8.2	New London	3.90	29.79	SW. 20	SE. 8	NE. 12	N. 61 E.	181	.61
48	8.3	New London	3.40	29.74	SE. 8	NE. 12	E. 7	N. 68 E.	108	.69
49	9.2	New London	2.23	29.72	E. 7	N. 8	NW. 7	*	00	.72
50	13.2	Mount Washington	2.75	30.30	NW. 12	N. 8	NW. 12	N. 13 W.	151	.89
51	21.3	Chicago	2.00	29.81	SW. 15	NE. 8	NE. 20	*	00	.81
52	Sept. 5.1	Grand Haven	2.03	29.89	SE. 8	W. 16	W. 17	S. 17 E.	265	.72
53	7.2	Sydney, Canada	2.01	29.84	E. 5	E. 15	W. 22	N. 63 E.	195	.51
54	16.2	Washington	2.37	29.96	E. 10	NE. 12	NE. 9	N. 22 W.	148	.90
55	Oct. 8.3	Long Branch	2.11	29.82	S. 35	NW. 15	SW. 10	*	00	.82
	1877.									
56	Mar. 26.2	New London	2.04	29.72	NE. 20	NE. 8	E. 16	N. 56 E.	452	.34
57	27.1	Mount Washington	2.04	29.67	SE. 78	SE. 60	SE. 60	N. 37 E.	315	.31
58	27.2	Mount Washington	2.00	29.63	SE. 60	SE. 60	SE. 66	N. 37 E.	315	.22
59	April 30.2	Eastport	2.00	29.72	E. 21	E. 19	N. 2	*	00	.72
60	May 16.2	Leavenworth	2.10	29.82	S. 10	SE. 6	S. 13	S. 27 E.	585	.42
61	19.1	Duluth	2.10	29.85	SE. 2	NE. 10	E. 10	N. 66 E.	424	.49
62	20.2	Dubuque	2.17	29.50	S. 4	S. 20	SW. 10	S. 25 E.	90	.36
63	30.3	St. Paul	2.04	29.48	SE. 12	SE. 4	SE. 14	S. 70 E.	385	28.98
64	June 6.3	New London	2.13	29.80	SE. 14	E. 12	E. 9	N. 42 E.	217	29.65
65	7.3	Leavenworth	2.30	29.74	SE. 5	N. 10	N. 8	S. 68 W.	226	.62
66	11.1	Kittyhawk	2.08	30.00	SW. 14	NW. 8	N. 13	North.	117	.96
67	21.3	Washington	2.17	29.72	S. 27	NW. 5	NW. 12	S. 48 W.	496	.57
68	23.1	Pembina	2.06	29.44	NW. 22	SE. 13	E. 1	N. 47 E.	206	.28
69	24.1	Fort Garry	2.32	29.26	E. 14	SW. 16	SW. 17	*	00	.26
70	29.3	St. Paul	3.21	29.35	SE. 17	SE. 12	SW. 20	S. 70 E.	385	.28
71	July 1.1	Oswego	3.57	29.67	S. 9	SE. 8	W. 11	S. 71 E.	370	.45
72	6.1	Breckenridge	2.02	29.78	N. 20	SE. 16	SE. 24	S. 80 E.	200	.62
73	7.1	Breckenridge	2.00	29.69	SE. 12	SE. 3	NE. 12	S. 80 E.	200	.60
74	8.1	La Crosse	2.69	29.85	SE. 8	S. 10	NW. 8	S. 44 W.	273	.67
75	18.1	Louisville	2.05	29.82	S. 3	E. 4	W. 12	S. 8 E.	568	.59
76	19.2	Mount Washington	2.04	30.07	S. 50	SW. 30	SW. 25	S. 67 E.	328	.50
77	27.2	Rochester	2.05	26.96	W. 2	Calm.	SW. 5	N. 78 E.	78	.95
78	29.2	Washington	2.34	29.81	SW. 1	Calm.	SW. 4	S. 45 E.	198	.76
79	30.1	Mount Washington	2.00	30.24	NW. 5	NE. 4	N. 20	S. 25 W.	351	.78
80	31.3	Keokuk	2.00	29.95	S. 11	NW. 5	NE. 6	N. 68 E.	212	.82
81	Aug. 6.2	Keokuk	2.20	29.76	SW. 6	S. 4	SW. 6	S. 28 W.	423	.64
82	7.3	Portland, Me	2.32	29.69	S. 5	Calm.	E. 2	*	00	.69
83	9.3	Portland, Me	2.10	29.77	E. 12	NE. 11	N. 8	S. 66 E.	424	.66
84	13.2	Cape May	2.05	29.87	S. 14	NE. 2	S. 16	N. 85 E.	117	.85
85	23.3	Alpena	2.23	29.82	NE. 6	E. 20	W. 2	N. 7 W.	195	.77
86	27.1	La Crosse	2.55	29.98	S. 12	N. 4	W. 6	*	00	.98
87	28.1	Dubuque	2.65	30.08	W. 3	SW. 17	SW. 2	N. 76 E.	293	.91
88	31.3	Sandusky	2.10	29.80	S. 30	S. 16	NW. 16	*	00	.80
89	Sept. 7.1	Norfolk	2.21	29.99	S. 8	S. 4	N. 14	N. 25 W.	126	.95
90	15.2	Norfolk	2.12	29.97	SE. 1	E. 1	E. 3	N. 25 W.	126	.91
91	20.1	Kittyhawk	2.05	29.95	NE. 28	NE. 24	NE. 20	N. 64 E.	817	.60
92	28.2	Kittyhawk	2.24	29.72	NE. 22	NE. 48	NE. 30	North.	58	.63
93	28.3	Kittyhawk	2.10	29.69	NE. 48	NE. 30	NE. 46	North.	58	.62
94	Oct. 4.1	Lynchburgh	2.07	29.41	SE. 8	NE. 8	NW. 12	*	00	.41
95	4.2	Washington	3.69	29.32	SE. 13	N. 30	NW. 18	*	00	.32
96	4.3	New York	3.95	29.44	SE. 20	N. 26	W. 21	North.	67	.36
97	5.1	Boston	3.99	29.46	SE. 8	NW. 28	NW. 24	*	00	.46
98	9.1	Barnegat	2.60	30.03	SE. 32	NW. 12	NW. 9	*	00	30.03
99	21.3	Norfolk	2.11	29.53	S. 21	SW. 12	W. 12	S. 27 W.	228	29.45
100	Nov. 2.3	Eastport	2.02	29.16	SE. 27	SW. 21	SW. 18	S. 8 E.	276	.06
101	9.1	Mount Washington	2.66	29.85	S. 96	W. 78	NW. 72	S. 4 W.	211	.54
102	23.3	Lynchburgh	2.10	29.63	NE. 9	NE. 14	SE. 4	*	00	.63
103	24.2	Atlantic City	2.15	29.95	E. 44	NE. 44	NE. 40	N. 88 E.	540	.70
104	24.3	Barnegat	2.52	29.92	E. 43	E. 40	S. 12	S. 69 E.	496	.69
105	25.1	Barnegat	2.46	29.80	E. 40	S. 12	S. 5	S. 75 E.	65	.78
106	Dec. 26.3	Kittyhawk	3.30	29.48	NE. 30	NE. 56	NE. 44	*	00	.48

238. The distribution of these 106 cases by seasons was as follows: Winter, 7; spring, 14; summer, 53; and autumn, 32.

We thus see that these great rains occur most frequently during that period of the year in which the atmosphere contains the greatest amount of vapor.

These great rainfalls afford some indication of a diurnal inequality. The distribution of the cases according to the hours of the day was as follows:

At the 7:35 a. m. observation, 42 cases.
4:35 p. m. observation, 33 cases.
11:00 p. m. observation, 31 cases.

The intervals between the observations, which for convenience I have called 8 hours, are seen to be unequal. Making allowance for the inequality of the intervals, the observations indicate that in the United States north of latitude 36° heavy falls of rain are less frequent from 7:35 a. m. to 4:35 p. m. than during the remainder of the day.

These great rainfalls occur much more frequently near the Atlantic coast than at interior stations. Of the 106 cases included in Table CVIII, 60 occurred on or near the Atlantic coast, and 46 at the interior stations. As there were numerous changes in the stations during the period of the observations, the ratio of the number of the interior stations to the coast stations was variable, but for the entire period the former were nearly three times as numerous as the latter, showing that near the Atlantic coast north of latitude 36° great rainfalls occur *four* times as frequently as in the interior of the United States east of the Rocky Mountains. This fact accords with the results stated in the preceding part of this chapter.

The average distance of the rain center from the center of low pressure was 212 miles, and the average height of the barometer at the low center was 29.63 inches. The average height of the barometer at the stations of greatest rainfall was 29.77 inches.

The rain center was generally on the east side of the low center, and the number of cases for each of the four quadrants was as follows:

In the NE. quadrant, 30 per cent. of the whole number.
SE. quadrant, 28 per cent. of the whole number.
NW. quadrant, 9 per cent. of the whole number.
SW. quadrant, 9 per cent. of the whole number.
The two centers coincident 24 per cent. of the whole number.

239. For the 7 cases which occurred in winter, the average distance of the rain center from the center of barometric depression was 177 miles; and the average height of the barometer at the low center was 29.50 inches. We thus see that the greatest rains are generally associated with areas of low pressure of only moderate depression. Of the 106 cases enumerated in Table CVIII, in only one case did the barometer sink as low as 29 inches, although we have found from Table XLIX that in the United States and Canada the barometer sinks below 29 inches on an average 17 times annually, as indicated by tridaily observations. In the case of No. 35, there was a lower pressure (29.89) at Indianola, but the rainfall at Nashville seemed to be associated with a slight local disturbance of which Nashville was the center. The accompanying plates exhibit the phenomena attending these great rainfalls better than a simple description. Plate XXXIX, Fig. 2, shows for No. 33 the area of 1 inch rainfall, and also the area of a half inch rainfall and a quarter inch rainfall. It also exhibits the isobars for the same date, together with the direction and velocity of the wind. One feather attached to an arrow indicates a velocity not exceeding 5 miles per hour; 2 feathers indicate a velocity from 5 to 10 miles per hour; 3 feathers indicate a velocity from 10 to 15 miles per hour; 4 feathers from 15 to 20 miles per hour, etc. The cyclonic motion of the wind is distinctly marked, and we see that the rain was mostly on the southeast side of the low center. The rain area stretched from NE. to SW. a distance of 1,000 miles, its center being not far from Louisville.

Plate XXXVIII, Fig. 1, shows a similar rain area stretching along the coast over 1,000 miles, its center being not far from Washington.

Plate XXXVIII, Fig. 2, shows a similar rain area stretching nearly 1,000 miles along the coast, its center being not far from Boston.

Plate XL, Fig. 1, presents a case of very feeble barometric gradients, and there were formed three rain centers of over 1 inch rainfall, in two of which there was a cyclonic movement of the winds imperfectly developed. For the third rain center the observations were too few to enable us to pronounce respecting a cyclonic movement.

Plate XXXIX, Fig. 1, shows a case in which the rain area was on the southwest side of the low center, but the barometric gradients were feeble, and the rain center was the center of an imperfectly developed cyclonic movement of the winds. The accompanying plates exhibit in like manner for 26 cases the rain areas of a quarter inch, a half inch, and 1 inch in 8 hours, all bounded by dotted lines; also isobars represented by continuous black lines; and the direction of the wind indicated by arrows, on which the number of feathers shows the wind's velocity.

240. For the 53 cases of great rains which occurred during the summer months, the average distance of the rain center from the center of low pressure was 200 miles and the average height of the barometer at the low center was 29.70 inches. These results show a less intimate connection between a great rainfall and a large area of depressed barometer, for while the barometric depression is less in summer than in winter, the average distance of the rain center from the low center is greater in summer than in winter, indicating that the great rainfalls of summer are influenced by local causes more than those of winter.

Among the 106 cases enumerated in Table CVIII, the most remarkable are those of August 8 and 9, 1874 (Nos. 46–49). A general idea of the phenomena attending this extraordinary rainfall may be derived from Plate XXXVI, Fig. 2, which shows the area of 1 inch rainfall about New London, and also the area of a half inch rainfall, and a quarter inch rainfall for August 8, 7:35 a. m.

The area of 3 inches rainfall was confined to a district of small extent near New London, and there was another rain center at Toledo amounting to nearly 1 inch in 8 hours.

The plate shows the isobars for the given date, together with the direction and force of the wind. The cyclonic movement of the wind was not very decided, the barometric depression being small.

The continuance of this heavy rainfall for 40 successive hours, its center remaining almost stationary for this entire period, is very extraordinary. The following observations of the rainfall at the Signal Service station at New Haven (50 miles west of New London) confirm the accuracy of the observations at New London, and show that during the night of August 8 and 9 the rain center moved a little westward from New London.

New Haven, Conn., Aug. 8.1=1.24 inches; 8.2=2.82 inches; 8.3=3.54 inches; 9.1=2.37 inches; 9.2=1.77 inches.

During these 40 hours from August 7.3 to August 9.2 the total rainfall at New London was 14.53 inches; while at New Haven it was 11.74 inches. The extraordinary character of this rainfall will appear from the following statement. Rainfall observations at New Haven were commenced in 1804, and have been continued with interruptions to the present time, furnishing 44 entire years of observations. During these 44 years there have been only 8 cases in which the rainfall for an entire month has amounted to 10 inches. The following are the dates of these cases, together with the rainfall for the corresponding months:

July, 1828, 11.10 inches; Aug., 1874, 12.99 inches; July, 1876, 11.05 inches; Mar., 1881, 10.42 inches.
Oct., 1869, 10.51 inches; Mar., 1876, 10.15 inches; Oct., 1877, 10.09 inches; Sept., 1882, 13.43 inches.

It is thus seen that the rainfall for the month of August, 1874, at New Haven, has been equaled only once in 44 years, viz, in September, 1882, and in the latter case the greatest amount of rain that fell on any two successive days was 4.28 inches, whereas in August, 1874, there fell in 40 successive hours 11.74 inches, showing that the rainfall of August 8 and 9, 1874, was by far the most remarkable that has ever been recorded in New Haven.

The rain of August 8–9, 1874, fell under circumstances corresponding very closely with the average conditions of the other cases enumerated in Table CVIII. At the 7 a. m. and 4 p. m. observations the rain center was on the east side of the low center, and at a distance from it less than 200 miles, and the low center advanced towards the rain center until the evening of August 8, when the two centers were apparently coincident. The conditions were favorable for a considerable rainfall at New London, but the published observations are too few to indicate the cause of

a rain so extraordinary in amount. It is evident that there was a strong uprising of the air in the neighborhood of New London, and this air coming directly from the ocean contained a large amount of vapor, and the source from which this vapor was drawn was inexhaustible. This was a case of what Espy called a *spout*, and we can see that the conditions were favorable for a spout of considerable intensity and of long continuance.

241. Generally a rainfall amounting to 2 inches in 8 hours does not last more than 8 hours either at the same station or at any neighboring station. Among the 106 cases in Table CVIII there are only 5 cases in which 2 inches of rain fell in two successive periods of 8 hours at the same station, and there are 4 other cases in which 2 inches of rain fell in the succeeding 8 hours at a second station so near the first station that the rain may be presumed to have fallen at this rate uninterruptedly for 16 hours or more. Table CIX shows a list of these cases.

TABLE CIX.—*Cases of heavy rain continuing more than* 8 *hours.*

Date.	Rain.	Station.	Date	Rain.	Station.	Date.	Rain.	Station.	Date.	Rain.	Station.	Date.	Rain.	Station.
1873.	*In.*			*In.*			*In.*			*In.*			*In.*	
June 22.3	22.8	St. Paul.....	23.1	2.30	St. Paul.....	....	....	.....	....	....	.....	....	....	.....
July 27.2	2.12	Washington.	27.3	2.03	Philadelphia	....	....	.....	....	....	.....	....	....	.....
Aug. 13.1	2.31	Philadelphia	13.2	2.17	Philadelphia	13.3	3.26	Baltimore	....	....	.....	....	....	.....
Dec. 3.2	2.32	Indianapolis	3.3	2.30	Louisville...	....	....	.....	....	....	.....	....	....	.....
1874.														
Aug. 8.1	4.45	New London	8.2	3.90	New London	8.3	3.40	N. London	9.1	2.37	N. Haven	9.2	2.23	N. London
1877.														
Mar. 27.1	2.04	Mt. Washington.	27.2	2.00	Mt. Washington.	....	....	.....	....	....	.....	....	....	.....
Sept. 28.2	2.24	Kitty Hawk.	28.3	2.10	Kitty Hawk.	....	....	.....	....	....	.....	....	....	.....
Oct. 4.1	2.07	Lynchburgh	4.2	3.69	Washington.	4.3	3.95	New York	5.1	3.99	Boston ..	....	....	.....
Nov. 24.2	2.15	Atlantic City	24.3	2.52	Barnegat....	25.1	2.46	Barnegat.	....	....	.....	....	....	.....

Thus we find nine cases in which a rainfall of 2 inches in 8 hours continued for 16 hours, four cases in which it continued for 24 hours, two cases in which it continued for 32 hours, and one case in which it continued for 40 hours.

242. Table CX shows all the cases in which a rainfall of at least $2\frac{1}{2}$ inches in 8 hours occurred during the 41 months of observations, at any station East of the Rocky Mountains, and South of the parallel of 36°. The arrangement of the table is the same as that of Table CVIII.

TABLE CX.—*Rainfall of* $2\frac{1}{2}$ *inches in* 8 *hours at stations South of latitude* 36° *United States.*

No.	Date.	Station.	Rain.	Barom.	Direction and velocity of the wind.			Rain center from low.		Low barom.
					Prev. obs.	At date.	Sub. obs.	Direction.	Dist.	
	1872.		*In.*					°		
1	Nov. 6.1	Galveston	3.75	29.76	E. 2	SE. 28	N. 18	N. 64 E.	136	29.70
2	6.3	Montgomery	2.73	29.95	E. 3	SE. 22	NW. 2	N. 42 E.	153	29.91
3	8.1	New Orleans	3.15	29.85	NE. 16	N. 18	NE. 20	*	00	29.85
	1873.									
4	May 1.2	Montgomery	3.05	29.87	SE. 4	SE. 4	SE. 7	S. 27 E.	485	29.40
5	June 10.3	Memphis	2.68	29.98	SE. 8	NE. 4	NW. 4	S. 20 W.	122	29.95
6	July 22.2	Mobile	3.14	30.18	NE. 16	E. 16	SE. 1	N. 75 E.	392	30.08
7	Aug. 2.2	Punta Rassa	3.32	30.06	NE. 4	N. 2	SE. 5	N. 9 W.	180	30.02
8	17.3	Punta Rassa.....	2.69	30.11	SW. 13	E. 5	SE. 8	S. 53 E.	436	29.96
9	20.2	Jacksonville.....	3.72	30.06	SE. 4	E. 20	S. 2	S. 87 E.	382	29.94
10	21.1	Galveston	3.67	29.95	E. 5	Calm.	S. 9	*	00	29.95
11	Sept. 13.2	Galveston	2.95	29.99	NE. 9	NE. 14	N. 13	N. 68 E.	133	29.98
12	18.2	Mobile	2.73	29.90	E. 12	E. 12	N. 10	N. 64 E.	136	29.81
13	26.2	Indianola	2.96	29.85	SE. 20	S. 14	SE. 13	*	00	29.85
14	Oct. 3.1	Jacksonville	2.74	30.04	N. 12	NW. 4	NE. 20	N. 6 E.	488	29.84
15	Nov. 2.3	Galveston	3.50	30.05	S. 16	S. 12	NE. 8	*	00	30.05
16	5.2	Montgomery	2.97	30.06	Calm.	SE. 1	SE. 4	*	00	30.06
	1874.									
17	Feb. 18.1	Charleston	2.56	29.93	N. 16	N. 12	N. 14	*	00	29.93
18	Mar. 15.3	Mobile	2.88	29.97	S. 20	E. 8	S. 12	N. 74 E.	392	29.82

TABLE CX.—*Rainfall of* $2\frac{1}{2}$ *inches in* 8 *hours at stations South of latitude* 36°, *etc.*—Continued.

No.	Date.	Station.	Rain.	Barom.	Direction and velocity of the wind.			Rain center from low.		Low barom.
					Prev. obs.	At date.	Sub. obs.	Directions.	Dist.	
	1874.		*In.*					°		
19	April 8.2	Vicksburg	3.67	29.63	NE. 6	NE. 8	NE. 4	North.	208	29.55
20	May 27.2	Galveston	2.65	29.86	SE. 14	SE. 14	E. 20	N. 68 E.	133	29.85
21	June 24.2	Indianola	3.32	30.09	SE. 17	SE. 10	SE. 6	S. 68 W.	133	30.08
22	29.2	Punta Rassa	2.71	30.06	SW. 12	N. 14	E. 16	N. 4 E.	254	29.97
23	July 3.2	Savannah	2.85	30.04	S. 4	S. 3	S. 4	S. 52 W.	70	30.02
24	4.2	New Orleans	3.25	29.94	SE. 24	SE. 16	SE. 20	N. 82 E.	265	29.84
25	Aug. 19.1	Galveston	2.72	29.99	NE. 12	NE. 12	SE. 8	*	00	29.99
26	25.2	Jacksonville	2.80	29.98	W. 8	SE. 4	NE. 8	*	00	29.98
27	Sept. 25.3	Vicksburg	2.95	30.07	W. 2	E. 2	E. 3	N. 79 E.	151	29.88
28	28.1	Savannah	2.80	29.51	SE. 8	E. 12	W. 16	N. 22 E.	140	29.42
29	28.2	Charleston	2.57	29.49	SE. 30	W. 20	W. 8	S. 44 W.	172	29.24
30	Oct. 12.3	Key West	2.54	29.96	NW. 18	N. 18	NE. 22	N. 33 E.	150	29.76
	1875.									
31	Jan. 12.2	St. Marks	2.93	30.03	NE. 5	E. 10	E. 8	N. 89 E.	351	29.94
	1877.									
32	Jan. 21.1	Galveston	2.63	29.97	NW. 6	N. 26	N. 10	S. 84 W.	298	29.94
33	Mar. 1.2	New Orleans	2.59	29.64	SE. 14	SW. 12	SW. 8	S. 25 E.	180	29.62
34	April 7.3	Montgomery	3.77	29.33	SE. 7	E. 16	Calm.	*	00	29.33
35	8.2	Charleston	3.70	29.46	SE. 12	S. 13	NE. 7	S. 58 E.	448	29.25
36	13.1	Charleston	5.20	29.40	NE. 24	NE. 36	N. 10	N. 46 E.	95	29.34
37	13.2	Charleston	2.80	29.30	NE. 36	N. 10	NW. 20	*	00	29.30
38	June 8.2	Memphis	5.26	29.79	SE. 10	Calm.	NW. 10	S. 8 E.	362	29.59
39	9.1	Memphis	4.40	29.77	NW. 10	S. 8	NW. 14	S. 19 W.	133	29.68
40	12.1	Charleston	2.70	30.15	NW. 8	NE. 10	NE. 6	N. 7 E.	576	29.95
41	July 10.3	Savannah	2.80	29.92	S. 13	SW. 4	SW. 4	S. 15 W.	396	29.81
42	16.2	Uvalde	6.00	29.71	.....	SE. 12	.....	East.	31	29.66
43	22.1	Charleston	3.60	30.08	W. 3	W. 3	E. 9	N. 31 E.	203	30.04
44	Aug. 8.1	Memphis	2.78	29.89	NW. 12	N. 4	N. 10	*	00	29.89
45	9.2	Rio Grande City	2.65	29.95	.....	W. 4	.....	S. 13 E.	238	29.76
46	22.2	St. Marks	3.79	29.90	N. 9	SE. 4	Calm.	S. 78 E.	250	29.78
47	23.2	Wilmington	3.23	30.00	SE. 12	SW. 15	SE. 5	S. 47 E.	504	29.69
48	Sept. 1.3	Wilmington	3.19	29.86	SW. 18	NE. 10	SW. 3	S. 68 W.	148	29.77
49	4.1	Shreveport	6.00	29.93	E. 5	N. 4	NE. 4	N. 60 E.	338	29.70
50	5.2	Pilot Point	3.89	30.04	.....	NE. 6	.....	N. 26 E.	273	29.72
51	6.1	Galveston	3.20	30.02	SE. 5	SW. 1	NW. 3	*	00	30.02
52	12.2	Wilmington	3.05	30.09	Calm.	E. 5	S. 2	N. 72 E.	243	30.00
53	13.1	Charleston	3.00	30.11	S. 8	E. 5	E. 8	S. 44 E.	318	30.03
54	18.1	New Orleans	3.25	29.66	E. 20	E. 24	E. 28	*	00	29.66
55	18.2	Mobile	4.85	29.72	N. 20	NE. 16	NE. 26	N. 62 E.	125	29.43
56	28.2	Cape Hatteras	4.00	29.63	SE. 33	SE. 20	S. 10	*	00	29.63
57	Oct. 14.1	Denison	3.40	29.93	SE. 16	N. 12	NE. 3	S. 30 W.	151	29.84
58	14.2	Pilot Point	4.60	29.96	.....	NE. 4	.....	N. 26 E.	275	29.62
59	16.2	Indianola	3.87	29.87	SE. 13	NE. 44	N. 28	N. 36 E.	178	29.74
60	24.3	Galveston	3.94	29.90	SE. 11	S. 12	N. 4	S. 83 E.	239	29.74
61	25.3	Galveston	3.88	29.82	SE. 11	E. 12	SW. 3	S. 83 E.	239	29.70
62	30.1	New Orleans	3.40	29.99	SE. 14	E. 12	N. 4	*	00	29.99
63	Nov. 1.2	Pilot Point	3.06	29.81	.....	NW. 10	.....	N. 65 W.	195	29.64
64	1.3	Vicksburg	2.50	29.76	S. 10	NW. 10	NW. 12	S. 30 W.	565	29.38
65	5.1	Indianola	2.95	30.03	SE. 6	N. 18	N. 30	S. 59 W.	118	29.98
66	8.2	Charleston	3.80	29.79	SE. 8	S. 7	SW. 11	S. 19 E.	644	29.47
67	Dec. 29.3	Cape Lookout	3.04	29.28	E. 40	W. 34	W. 32	S. 54 W.	71	29.26

243. The distribution of these 67 cases by seasons was as follows: Winter 4; Spring 9; Summer 22, and Autumn 32. The greatest number of cases occurred in the autumn, while north of latitude 36° the greatest number occurred in summer. The month of greatest frequency south of latitude 36° is September, while north of latitude 36° the month of greatest frequency is July, but August shows an almost equal number of cases. The difference, therefore, in the date of maximum frequency for the northern and southern parts of the United States is not very great, and may disappear in a longer series of observations.

The distribution of these cases of heavy rain according to the hours of the day was as follows:

At the 7:35 a. m. observation, 20 cases.
4:35 p. m. observation, 33 cases.
11:00 p. m. observation, 14 cases.

If we make allowance for the inequality of the intervals, we find that south of latitude 36° heavy falls of rain are much more frequent from 7:35 a. m. to 4:35 p. m. than during the remainder of the day, while north of latitude 36° the middle of the day is the period of least frequency.

These great rainfalls occur somewhat more frequently near the coast of the Atlantic or the Gulf of Mexico than at interior stations. Of the 67 cases included in Table CX, 46 occurred on or near the coast, and 21 occurred at interior stations. During the period of these observations the number of coast stations was somewhat greater than the interior stations, and the average number of great rainfalls at the coast stations was about one-half greater than at interior stations. This is a difference very much less than we have found for the northern portion of the United States.

The average distance of the rain center from the center of low pressure was 198 miles, and the average height of the barometer at the low centers was 29.77 inches, which results accord pretty closely with those for the Northern stations during the summer months.

The rain center was generally on the east side of the low center, and the number of cases for each of the four quadrants was as follows:

In the NE. quadrant, 34 per cent. of the whole number.
SE. quadrant, 21 per cent. of the whole number.
NW. quadrant, 5 per cent. of the whole number.
SW. quadrant, 18 per cent. of the whole number.
The two centers coincident, 22 per cent. of the whole number.

The most noticeable difference between these results and those for the northern portion of the United States is a less number of cases in the southeast quadrant, and a greater number in the southwest quadrant. This difference may perhaps be ascribed to the fact that in the southern portion of the United States the Gulf of Mexico is an important source of the vapor which is precipitated, while in the northern portion the Atlantic Ocean affords the principal supply.

244. Among the 67 cases enumerated in Table CX, there is only one case in which $2\frac{1}{2}$ inches of rain fell in two successive periods of 8 hours, at the same station, and there are three other cases in which $2\frac{1}{2}$ inches of rain fell in a second period of 8 hours at a station near the first. Table CXI shows a list of these cases.

TABLE CXI.—*Cases of heavy rain continuing more than 8 hours.*

Date.	Rain.	Station.	Date.	Rain.	Station.
	Inches.			*Inches.*	
1874. Sept. 28. 1	2. 80	Savannah.	1874. Sept. 28. 2	2. 57	Charleston.
1877. April 13. 1	5. 20	Charleston.	1877. April 13. 2	2. 80	Charleston.
Sept. 18. 1	3. 25	New Orleans.	Sept. 18. 2	4. 85	Mobile.
Oct. 14. 1	3. 40	Denison.	Oct. 14. 2	4. 60	Pilot Point.

Thus we see that while heavy rains are of more frequent occurrence in the southern part of the United States than they are in the northern part, they have a less period of duration.

Plate XLI will give a more precise idea of the peculiarities of some of these cases. Fig. 2 represents No. 36, a rainstorm which occurred near Charleston, S. C., April 13, 1877. The isobars for 29.4, 29.5, etc., are represented by continuous black lines, and the rainfall for the 8 hours preceding the morning observation is indicated by dotted lines. The figure shows the rain area of 2 inches, 1 inch, a half inch, and a quarter inch. The arrows show the direction and force of the wind. We see that the rainfall of 5.20 inches observed at Charleston must have been very limited in extent. In this vicinity the wind blew with extreme violence, and the motion of the winds was cyclonic, with an unusually strong tendency inward. Near the center the upward

motion of the wind must have been unusually strong; that is, it formed a *spout*, and the heavy rain which accompanied it was the necessary result of this strong upward movement of the air. No. 28, Plate XII, Fig. 1, was similar to the preceding.

Plate XLII, Fig. 1, represents a case (No. 19), which is not very unusual, and numerous examples of it have been found. It was a case in which the rainfall was almost wholly on the north side of the low center. There was a center of high pressure in the northern part of the United States (Breckenridge, 30.37 inches). From this point the pressure diminished quite uniformly to the minimum at New Orleans. The result was a general system of northerly winds extending from the high center nearly to the Gulf of Mexico, while fresh winds blew from the south at New Orleans and Mobile. The northerly winds pushed under the southerly winds, and lifted them up from the earth's surface, and the southerly winds probably continued their northerly course considerably north of the low center. This is shown by the observations at Montgomery, where the surface winds were from the north, but the upper clouds were from the south. Also at Dubuque the upper clouds were from the south, while the winds were from the northwest. The general rainfall on the northern side of the low center was the result of this mechanical uplifting of the air, and when a general upward movement had commenced, it became especially strong at certain places. No. 5 illustrates the same principle. Cases 1, 34, 54, and 85 of Table CVIII, appear to have resulted from the operation of the same principle. We have also seen the same principle exemplified in article 230.

245. We have seen from Tables CVIII and CX that the depression of the barometer accompanying extraordinary rainfalls is not very great; the average pressure at the low center being 29.63 inches for that part of the United States north of latitude 36°, and the average pressure at the stations of greatest rainfall being 29.77 inches. In order to show what effect is produced upon the rainfall by an extraordinary depression of the barometer, I have prepared Table CXII, which contains all the cases in which the barometer fell below 29 inches at any station in the United States or Canada during the period from September, 1872, to June, 1884. The dates are taken from Tables XLIX and L of chapter II. Column 3 shows the station at which the lowest pressure was observed; column 4 shows the pressure at that station; column 5 shows the station at which the greatest rainfall was reported for the preceding 24 hours; and column 6 shows the amount of the rainfall in 24 hours at the stations named.

TABLE CXII.—*Rainfall in 24 hours with barometer below 29 inches.*

No.	Date.	Low Pressure.		Rain-fall in 24 hours.	
		Station.	Barom.	Station.	Rain.
	1873.				
1	Mar. 29.3	Burlington, Vt	28.80	Oswego	2.30
2	30.1	Portland, Me	28.87	Oswego	2.58
3	Aug. 24.3	Halifax	28.99	Halifax	2.11
4	Nov. 9.1	Cape Rozier	28.96	Eastport	2.27
5	13.1	Cape Rozier	28.99	Halifax	1.99
6	17.2	Norfolk	28.82	Knoxville	1.99
7	17.3	Cape May	28.82	Boston	1.53
8	18.1	New London	28.66	Boston	3.01
9	18.2	Eastport	28.47	Boston	3.45
10	18.3	Chatham	28.64	Boston	1.95
11	19.1	Cape Rozier	28.97	Sydney	1.64
12	25.1	Halifax	28.82	Boston	1.30
13	25.2	Sydney	28.80	Chatham	1.43
14	25.3	Sydney	28.78	Chatham	1.35
15	26.1	Sydney	28.85	Cape Rozier	0.90
16	Dec. 4.1	Marquette	28.91	Indianapolis	3.40
17	28.1	Portland, Me	28.93	Mount Washington	0.98
18	28.2	Eastport	28.91	Halifax	1.28
19	28.3	Sydney	28.98	Halifax	1.28
	1874.				
20	Feb. 11.1	Sydney	28.78	Sydney	0.58
21	11.2	Sydney	28.84	Sydney	0.73
22	Mar. 11.3	Sydney	28.90	Ottawa	0.40

TABLE CXII.—*Rainfall in 24 hours with barometer below 29 inches*—Continued.

No.	Date.	Low pressure.		Rainfall in 24 hours.	
		Station.	Barom.	Station.	Rain.
	1874.				
23	Mar. 12.1	Cape Rozier	28.87	Father Point	0.33
24	12.2	Cape Rozier	28.90	Father Point	0.33
25	12.3	Cape Rozier	28.85	Father Point	0.33
26	13.1	Cape Rozier	28.86	Cape Rozier	0.40
27	19.3	Father Point	28.97	Mount Washington	1.49
28	Apr. 30.2	Father Point	28.97	Eastport	1.33
29	Sept. 30.2	Father Point	28.94	Albany	2.10
30	Nov. 22.3	Chicago	28.82	Cairo	2.52
31	23.1	Alpena	28.75	Cairo	2.43
32	23.2	Alpena	28.93	Barnegat	2.43
33	23.3	Portland, Me	28.87	Barnegat	2.35
34	24.1	Cape Rozier	28.89	Halifax	1.28
35	24.2	Cape Rozier	28.91	Sydney	1.24
36	Dec. 24.3	Sydney	28.98	Sydney	0.60
	1875.				
37	Jan. 2.3	Halifax	28.89	Squam Beach	1.10
38	3.1	Sydney	28.89	Chatham	1.00
39	Feb. 4.1	Cape Rozier	28.79	Squam Beach	1.30
40	26.1	Sydney	28.85	Boston	1.18
41	28.1	Sydney	28.94	Halifax	0.68
42	Mar. 15.2	Toledo	28.96	Cape Hatteras	2.09
43	16.1	Marquette	28.88	Cape Hattetas	2.50
44	Nov. 11.1	Eastport	28.96	Newport	3.16
45	11.2	Charlottetown	28.97	Boston	1,91
46	17.1	Charlottetown	28.43	Halifax	1.13
47	17.2	Sydney	28.80	Eastport	0.92
48	17.3	Sydney	28.91	Eastport	0.72
49	Dec. 13.1	Ottawa	28.94	Toronto	0.64
50	13.2	Sydney	28.88	Sydney	0.44
51	13.8	Sydney	28.81	Sydney	0.33
52	14.1	Sydney	28.86	Stayner	1.07
	1876.				
53	Jan. 20.1	Dalhousie	28.90	Frederick	0.90
54	Feb. 2.1	Thatcher's Island	28.75	St. John	1.43
55	2.2	Chatham	28.25	Eastport	1.92
56	2.3	Sydney	28.90	Eastport	1.90
57	15.2	Burlington, Vt	28.79	Father Point	2.19
58	15.3	Montreal	28.99	Father Point	2.20
59	25.2	Sydney	28.99	Port Hastings	0.30
60	Mar. 16.2	Grand Haven	28.96	Knoxville	2.33
61	17.3	Eastport	28.92	Montreal	1.10
62	18.1	Charlottetown	28.93	Chatham	1.05
63	Oct. 5.1	Pembina	28.92	Memphis	1.92
64	16.1	Bathurst	28.75	Chatham	1.50
65	Dec. 1.2	Sydney	28.97	Sydney	0.61
66	9.1	Cornwall	28.99	Parry Sound	0.85
67	9.2	Eastport	28.80	Parry Sound	0 77
68	9.3	Eastport	28.83	Halifax	0.57
69	10.1	Sydney	28.90	Mount Washington	1.11
70	19.1	Bathurst	28.96	Fredericton	2.07
71	29.3	Albany	28.89	Cape May	1.34
72	30.1	Portland, Me	28.90	Brockville	1.80
73	30.2	Father Point	28.94	Montreal	1.48
74	30.3	Chatham	28.94	Montreal	1.42
	1877.				
75	Jan. 2.2	Sydney	28.93	New York	1.12
76	2.3	Sydney	28.76	New York	0.95
77	7.2	Eastport	28.96	New London	1.66
78	20.2	Father Point	28 93	Knoxville	1.70
79	Mar. 9.1	Malone	28.87	Knoxville	2.30
80	9.2	Father Point	28.74	Kingston	1.66
81	May 30.2	Bismarck	28.79	St. Paul	2.04
82	30.3	Bismarck	28.98	St. Paul	2.04
83	31.1	Bismarck	28.98	St. Paul	2.28
84	31.2	Bismarck	28.97	St. Paul	2.28
85	Nov. 3.1	Father Point	28.92	Eastport	2.37
	1878.				
86	Jan. 11.1	Portland, Me	28.86	Kitty Hawk	3.04
87	Feb. 11.1	Little Glace Bay	28.97	Charlottetown	1.55
88	Mar. 25.1	Father Point	28.82	Mount Washington	1.03

TABLE CXII.—*Rainfall in 24 hours with barometer below 29 inches*—Continued.

No.	Date.	Low Pressure.		Rain-fall in 24 hours.	
		Station.	Barom.	Station.	Rain.
	1878.				
89	Apr. 6.1	Halifax	28.83	Sydney	0.83
90	10.1	St. Paul	28.74	Breckenridge	3.83
91	Aug. 20.1	Little Glace Bay	28.77	Little Glace Bay	3.93
92	Oct. 23.1	Baltimore	28.83	Smithville, N. C	4.32
93	Nov. 23.1	Quebec	28.93	Quebec	2.30
94	Dec. 11.1	Montreal	28.99	Oswego	2.81
	1879.				
95	Jan. 3.1	Eastport	28.58	Quebec	1.50
96	4.1	Halifax	28.58	Rochester	1.50
97	5.1	Heart's Content	28.75	Buffalo	1.06
98	10.1	Little Glace Bay	28.83	Newport	1.66
99	Feb. 2.1	Sydney	28.75	Mount Washington	0.74
100	21.1	Halifax	28.91	Boston	0.97
101	22.1	Sydney	28.97	Charlottetown	1.20
102	Apr. 1.1	Eastport	28.63	St. Andrews	1.40
103	2.1	Father Point	28.92	Bathurst	1.42
104	4.1	Halifax	28.93	Thatcher's Island	0.72
105	Oct. 29.1	St. Andrews	28.85	St. Andrews	2.01
	1880.				
106	Mar. 27.1	Davenport	28.91	Indianapolis	1.53
107	Apr. 19.1	Duluth	28.89	Madison	2.15
108	June 6.1	Madison	28.99	Alpena	2.54
109	Oct. 16.1	La Crosse	28.85	Louisville	3.10
110	Dec. 5.1	Escanaba	28.89	Cincinnati	3.09
111	30.1	Sydney	28.79	Little Glace Bay	1.50
	1881.				
112	Mar. 23.1	Sydney	28.89	Fort Macon	1.91
113	27.1	Sydney	28.89	Montreal	0.38
114	28.1	Sydney	28.91	Father Point	0.40
115	31.1	Thatcher's Island	28.96	Newport	2.93
116	Oct. 26 1	Sydney	28.94	Mount Washington	1.02
	1882.				
117	Jan. 2.1	Yarmouth	28.97	Halifax	1.22
118	14.1	Sydney	28.86	N. Shoreham	1.32
119	Mar. 14.1	St. Pierre	28.94	Father Point	0.60
	1883.				
120	Mar. 11.1	Father Point	28.86	Thatcher's Island	1.56
121	Sept. 25.1	Father Point	28.80	Washington	1.95
122	Oct. 30.1	Father Point	28.97	Halifax	2.76
123	Nov. 13.1	Little Glace Bay	28.75	Mackinaw	1.40
124	Dec. 22.1	St. Johns	28.72	St. Andrews	0.80
125	28.1	St. Andrews	28.73	Quebec	1.60
	1884.				
126	Feb. 29.1	Charlottetown	28.52	Portland, Me	1.98
127	Mar. 1.1	Anticosti	28.85	Quebec	0.60
128	3.1	Little Glace Bay	28.76	Halifax	0.68
129	Apr. 3.1	Yarmouth	28.89	Block Island	1.77
130	4.1	Yarmouth	28.73	Chatham	1.12
131	5.1	Halifax	28.98	St. John	0.36

The average rainfall in 24 hours at all these stations was 1.58 inches, and the greatest rainfall at any of the stations was 4.32 inches. At 38 of the stations the rainfall exceeded 2 inches, and at 34 stations the rainfall was less than 1 inch. In all of the cases in which the rainfall did not amount to 1 inch in 24 hours at any of the stations, the center of low pressure was over the Atlantic Ocean or very near the coast. There are only 5 cases which can be claimed as exceptions to this rule. In No. 53, the low center was over the Gulf of St. Lawrence; and in Nos. 67 and 68 the low center was over the Bay of Fundy. In No. 49 (according to Hoffmeyer's maps), there were two low centers, one near Ottawa and the other over the Atlantic Ocean South of Nova Scotia, the two centers being separated by a belt of 29.20 inches pressure. The winds in this vicinity were generally strong, and were mainly controlled by the Atlantic center. In No. 66 there were also two low centers, one near Montreal and the other near Boston, with a slightly increased pressure between these two centers. The isobar 29.20 inches was an elongated oval including both centers. The winds were very strong and were mainly controlled by the Boston center. At the end of 8 hours, the two low centers had coalesced.

246. We thus see that in each of the cases in which the rainfall did not amount to **1 inch in 24** hours at any of the stations, the eastern segment of the low area was over the Atlantic Ocean, where the amount of the precipitation could not be measured, and we have found that the greatest rainfall almost invariably occurs in this eastern segment. At three-fourths of all the stations the low center was over the Atlantic Ocean, or very near the coast. When the low center was over the interior of the continent the average rainfall at the principal rain centers was 2.48 inches; so that it seems reasonable to conclude that if we had observations from all parts of each of the low areas enumerated in Table CXII, the average rainfall for the principal rain centers would not be less than 2½ inches in 24 hours. Even this amount does not seem very large in comparison with the numbers in Table CVIII, and we seem forced to conclude that a moderate depression of the barometer is as favorable to great rainfall as an extremely great depression. This may seem to indicate that rainfall has but little connection with barometric depressions. It should, however, be remembered that the depression at the center of a low area depends not merely upon the barometric gradient, but upon the geographical extent of the low area. If at the center of a low area having a diameter of 1,000 miles, the depression of the barometer is one-half inch below the mean, at the center of a low area having a diameter of 2,000 miles with the same barometric gradient, the depression would be an entire inch below the mean. Now, according to Table L, the average breadth of these low areas was 2,140 miles. Over the Atlantic Ocean, the average breadth of the low area in which the barometer falls below 28.54 inches, is 2,365 miles (see article 139), and over the Pacific Ocean it is equally great (see article 172). In the United States when the lowest isobar is 29.5 inches, the average diameter of areas of low pressure is 1,185 miles, which is but little more than half the diameter of the low areas in Table CXII; which shows that when the barometer is most depressed, the average barometric gradient is but little greater than it is with a moderate depression. The extreme depression of the barometer shown in Table CXII, was due mainly to the unusual geographical extent of these low areas. This unusual extent was probably not due wholly to the atmospheric movements within these areas, but was influenced by the movements of distant areas of high and low pressure. The plates contained in Chapter II, show that each low area must be greatly influenced by the adjacent areas of high pressure. Plate XXVIII shows an area of low pressure over each of the Great Oceans, and an area of high pressure over each of the great continents, so that two areas of low pressure, with two areas of high pressure, make the entire circuit of the northern hemisphere. This distribution of pressure bears a close resemblance to the average distribution of pressure for the colder months of the year, and we naturally conclude that the causes which determine the average distribution of pressure for the colder months of the year were the principal causes which determined the distribution of pressure for December 15, 1882. The causes of this average distribution are two warm oceans and two cold continents. The same causes must have been influential in determining the distribution of pressure for December 15, 1882; and local causes of a more limited extent had only a secondary influence. When local causes have a predominating influence, the northern hemisphere is covered with a large number of low areas of irregular form and of unequal size, separated by an equal number of high areas exhibiting like variety.

247. I next examined those cases in which the total rainfall for all the stations was uncommonly great. Table CXIII exhibits all the cases from September, 1872, to November, 1873, in which the total rainfall at all the stations east of the Rocky Mountains amounted to at least 9 inches in 8 hours; also all the cases from December, 1873, to January, 1875, in which the total rainfall amounted to at least 10 inches in 8 hours; from January, 1877, to June, 1877, 11 inches, and from July, 1877, to December, 1877, 12 inches in 8 hours. This change in the amount of rainfall adopted as the standard was rendered necessary by the gradually increased number of the stations of observation.

In Table CXIII, column 1 shows the reference number; column 2 shows the day and hour of observation; column 3 shows (in inches) the total rainfall at all the stations east of the Rocky Mountains since the preceding observation; column 4 shows the station at which the greatest rainfall was recorded; column 5 shows (in inches) the amount of rain recorded at the stations mentioned in the preceding column; column 6 shows the height of the barometer at the same station; column 7 shows the height of the barometer at the nearest center of minimum pressure; column 8 shows the direction of the rain center mentioned in column 4, from the center of low pressure.

The middle of the rainfall is presumed to correspond to a date about 4 hours preceding the date of observation. I have therefore in each case determined a point midway between the low center at the given date and the low center at the preceding observation, and the directions given in column 8 were measured from this point. Column 9 shows the distance of the rain center from the center of low pressure determined in the manner just stated. Column 10 shows the direction in which the center of least pressure had advanced since the preceding observation; column 11 shows (in miles per hour) the rate at which this low center advanced; column 12 shows (in decimals of an inch) the average change of the barometer during the preceding 8 hours at neighboring stations situated on the front side of the low center; column 13 shows the average change of the barometer in 8 hours at neighboring stations situated on the rear side of the low center; column 14 shows the average change of the thermometer during the preceding 24 hours, at neighboring stations on the front side of the low center; and column 15 shows the average change of the thermometer during the same time at neighboring stations on the rear side of the low center. Column 16 shows for each date the number of rain areas at which the rainfall since the preceding observation amounted to at least one-half inch; and column 17 shows the velocity (in miles per hour) and also the direction of the highest wind reported at any of the stations which could be regarded as included within the influence of the low barometer traced in columns 10 and 11. Occasionally it happened that the same velocity was reported at several different stations. In such cases the direction of the wind is given for each of these stations.

TABLE CXIII.—*Total rainfall amounting to at least 9 inches in 8 hours, at stations east of the Rocky Mountains.*

No.	Date.	Total rainfall.	Station of greatest rain.	Rainfall.	Barometer.	Low barometer.	Rain center from low.		Low moved.		Bar. change in 8 hours.		Temp. change in 24 hours.		Rain areas.	Highest wind.
							Direction.	Dist.	Direction.	Rate.	Front	Rear.	Fr'nt	Rear		
													°	°		
	1872.															
1	Sept. 11.3	10.76	Marquette	1.91	29.80	29.74	N.18°E.	359	N.75°E.	51	—.02	+.12	0	— 3	8	55 NW.
2	12.2	9.93	Saugeen	1.74	29.74	29.68	N.57 E.	70	N.85 E.	30	—.12	+.09	0	— 7	6	20 N.
3	Oct. 23.1	9.34	Jacksonville	2.05	29.83	29.80	N.25 E.	128	North.	26	—.07	+.03	+ 5	— 5	1	16 E.
4	Nov. 6.3	9.91	Montgomery	2.73	29.95	29.91	N.26 E.	282	N.56 E.	50	—.10	+.11	+ 7	— 5	3	27 N.
5	7.1	13.52	New York	2.50	29.68	29.33	S.58 E.	800	S.64 E.	25	—.25	+.08	+ 5	0	1	20 N.; NW.
6	Dec. 20.1	14.29	New York	1.70	29.78	29.43	S.85 E.	463	N.53 E.	54	—.55	+.17	+ 8	0	5	33 NE.
	1873.															
7	Jan. 2.2	9.12	Keokuk	1.63	29.35	29.23	N.52W.	97	N. 8 E.	34	—.34	+.01	+11	— 5	4	28 NE.
8	5.1	12.02	Lake City	2.00	29.89	29.53	S.30 E.	476	N.64 E.	49	—.18	+.01	+ 6	— 7	3	25 E.
9	5.2	16.16	Philadelphia	2.18	29.61	29.45	East.	303	N.34 E.	44	—.47	+.23	0	— 6	4	32 NE.
10	16.1	10.08	New Orleans	2.01	29.92	29.59	S.15 W.	550	N.65 E.	24	—.23	+.17	+17	—27	4	31 N.
11	Feb. 16.1	10.54	Louisville	1.60	29.56	29.49	N.60 E.	223	N.19 E.	24	—.23	.00	+11	— 1	2	20 N.
12	16.2	9.60	Cape May	1.54	29.66	29.55	N.86 E.	594	N.79 E.	37	—.36	+.18	+ 6	— 3	3	36 NE.
13	Mar. 29.1	10.52	Lake City	2.00	29.97	29.31	S.19 W.	572	S.62 E.	47	—.34	+.15	+17	— 7	5	30 S.
14	29.2	10.42	Oswego	1.48	29.01	29.01	N.69 E.	62	N.72 E.	14	—.44	+.22	+ 2	—11	2	40 SE.
15	May 1.2	9.37	Montgomery	3.05	29.87	29.40	S.40 E.	476	S.78 E.	29	—.18	.00	+ 8	— 3	3	34 N.
16	2.1	11.74	Wilmington	1.01	29.88	29.42	S.53 E.	736	N.10W.	6	—.13	+.02	+ 2	— 3	3	23 NE.
17	June 30.2	9.20	Port Stanley	1.81	29.56	29.36	S.60 E.	733	S.51 E.	30	—.09	+.07	+ 3	— 7	5	25 NW.
18	July 17.3	10.88	Buffalo	2.00	29.64	29.64	S.60 E.	226	.....	0	—.01	+.04	+ 2	— 8	3	32 N.
19	27.2	9.63	Washington	2.12	30.11	30.04	.....	....	.....	..	.....	.....	....	....	5	30 S.
20	Aug. 13.1	9.52	Philadelphia	2.31	30.04	29.92	N.81 E.	312	S.21 W.	11	—.03	+.04	0	— 6	4	26 NE.
21	21.1	9.56	Galveston	3.67	29.95	29.95	.....	....	.....	..	.....	.....	....	....	4	12 NE.
22	Sept. 19.2	11.37	Cape May	1.92	29.70	29.57	S.10 E.	426	N.38 E.	32	—.17	+.08	+ 6	—20	6	24 SE.
23	24.1	9.51	Mt. Washington	1.55	.....	29.86	N.16 E.	770	N.76 E.	32	—.20	+.05	+ 3	— 3	3	14 NE.
24	Oct. 19.3	9.82	New London	2.25	29.80	29.52	N.32 E.	507	N.36 E.	43	—.15	+.15	+ 4	— 5	3	24 SE.
25	20.1	17.65	Philadelphia	1.96	29.47	29.45	N. 2 E.	156	N.23 E.	17	—.15	+.05	+ 4	— 7	1	46 E.
26	20.2	12.27	Rochester	1.38	29.65	29.26	N.22W.	273	N. 6W.	9	—.16	—.04	0	—17	3	42 E.
27	20.3	9.86	Buffalo	1.23	29.35	29.30	N.67W.	187	N.16W.	38	—.20	+.07	0	—14	3	45 E.
28	Nov. 18.2	9.16	Sydney	1.37	29.09	28.47	N.70 E.	457	N.48 E.	39	—.55	+.28	+ 8	— 9	3	41 E.
29	24.1	11.16	Nashville	1.08	29.86	29.48	S.39 W.	482	S.53 E.	15	—.39	+.07	+11	— 4	3	47 NE.
30	24.2	14.69	New London	2.80	29.30	29.27	S.85 E.	172	N.71 E.	55	—.43	+.02	+ 1	— 8	3	57 NE.
31	27.2	9.71	Charleston	1.75	29.91	29.81	.....	....	.....	..	.....	.....	....	....	2	20 S. [NW.
32	Dec. 3.1	10.65	St. Louis	1.35	29.66	29.54	South.	164	N.77 E.	22	—.13	+.06	+ 6	—20	4	24 S.; W.;]
33	3.2	10.02	Indianapolis	2.32	29.45	29.37	S.33 E.	180	S.20 W.	9	—.18	—.05	+12	—23	1	35 NW.
34	3.3	14.70	Louisville	2.30	29.55	29.08	S.20 E.	400	N.31 E.	28	—.32	+.07	+ 1	—24	2	43 W.[SW.
35	12.1	10.51	Cleveland	1.12	29.67	29.67	N.65 E.	364	N.63 E.	51	—.08	+.05	+12	— 5	2	20 N.; NW.;
	1874.															
36	Jan. 6.2	12.55	Wilmington	1.35	29.88	29.74	N.75 E.	384	S.78 E.	22	—.18	.00	+ 3	—13	3	31 NE.
37	7.1	11.81	Wilmington	1.03	29.77	29.57	S.62 E.	234	N.20 E.	38	—.13	—.10	+22	—21	3	26 E.

TABLE CXIII.—*Total rainfall amounting to at least* 9 *inches in* 8 *hours, etc.*—Continued.

No.	Date.	Total rainfall.	Station of greatest rain.	Rainfall.	Barometer.	Low barometer.	Rain center from low.		Low moved.		Bar. change in 8 hours.		Temp. change in 24 hours.		Rain areas.	Highest wind.
							Direction.	Dist.	Direction.	Rate.	Front.	Rear.	Frn't	Rear		
	1874.															
38	Jan. 22.1	10.20	St. Louis	1.52	29.70	29.66	S. 54 W.	257	S. 43 E.	13	—.15	+.18	+26	—14	3	24 S.
39	27.2	10.17	Rochester	1.16	29.75	29.51	East.	640	S. 80 E.	32	—.15	+.24	0	— 7	5	38 NE.
40	Feb. 13.1	10.12	Cairo	1.91	29.55	29.33	S. 28 W.	510	S. 48 E.	28	—.07	+.38	+21	—11	3	28 SE; S.
41	21.2	11.92	Cincinnati	1.45	29.87	29.82	N. 57 E.	292	N. 62 E.	41	—.03	+.08	+ 3	0	1	28 S; SW.
42	23.1	10.05	Erie	0.76	29.59	29.58	S. 83 E.	195	N. 40 E.	39	—.45	+.22	+ 6	— 7	5	65 E.
43	Mar. 6.1	10.93	Memphis	2.02	29.85	29.40	S. 76 E.	321	S. 74 E.	21	—.19	+.05	+ 3	— 3	2	24 SE.
44	Apr. 19.2	14.61	Vicksburg	2.49	29.72	29.47	S. 55 E.	343	N. 16 E.	25	—.42	.00	+ 7	0	2	28 E.
45	20.1	14.36	Milwaukee	1.43	29.51	29.38	N. 42 E.	306	N. 50 E.	38	—.15	+.22	+ 1	—10	6	34 E.
46	25.2	10.00	Knoxville	1.38	29.73	29.44	S. 84 W.	164	N. 58 E.	39	—.40	+.18	+ 3	— 2	3	38 E.
47	July 4.2	10.22	New Orleans	3.25	29.94	29.84	N. 82 E.	265	S. 40 E.	26	—.06	+.18	+ 6	0	2	24 S.; N.
48	Aug. 8.1	10.58	New London	4.45	29.88	29.75	S. 82 E.	315	N. 65 E.	36	—.10	+.01	+ 6	— 1	4	20 SW.
49	8.2	11.42	New London	3.90	29.79	29.61	S. 79 E.	180	South.	18	—.28	+.02	+ 5	— 5	4	18 W.; NW.
50	21.3	10.16	Chicago	2.00	29.81	29.75	N. 80 E.	180	S. 29 W.	20	—.01	+.10	0	—10	4	18 SE.; NE.
51	Sept. 18.3	10.27	Dubuque	1.94	29.73	29.60	N. 48 E.	200	N. 46 E.	32	—.02	+.33	0	—15	2	20 E.; NW.
52	28.1	13.01	Savannah	2.80	29.51	29.42	N. 42 E.	148	N. 71 E.	20	—.36	+.04	0	—12	2	30 SE.
53	Nov. 22.3	13.22	Cincinnati	1.61	29.34	28.82	S. 66 E.	335	N. 61 E.	40	—.40	+.47	+12	— 2	2	42 SE.
54	23.1	21.40	Barnegat	1.65	29.52	28.75	S. 73 E.	668	N. 45 E.	36	—.66	+.33	+ 6	0	3	37 W.
55	23.2	13.04	Portland, Me	1.62	29.18	28.93	S. 84 E.	660	N. 63 E.	18	—.12	+.45	+ 6	— 5	3	58 NE.
56	29.1	10.75	Washington	0.88	29.89	29.54	S. 33 W.	276	N. 35 E.	55	—.35	+.04	+11	— 7	1	50 NE.
57	29.2	13.31	Eastport	1.97	29.42	29.30	S. 17 E.	98	N. 64 E.	29	—.60	+.01	+16	— 7	5	70 S.
58	Dec. 7.1	14.83	Cape Henry	1.50	29.70	29.70	N. 22 E.	148	N. 35 E.	23	—.10	+.05	+10	0	2	24 NE.
59	20.2	14.00	Norfolk	1.26	29.33	29.32	N. 85 E.	231	N. 81 E.	52	—.53	+.35	+ 3	— 6	2	45 NE.
	1875.															
60	Jan. 2.1	13.98	Knoxville	1.03	30.05	29.64	South.	640	S. 51 E.	28	—.44	+.05	+14	— 9	4	28 N.; NW.
61	7.3	10.01	Long Branch	0.80	29.77	29.74	N. 17 E.	41	.....	0	—.17	+.02	+ 7	— 1	1	40 NE.
62	24.2	15.00	Barnegat	1.30	29.73	29.63	S. 56 E.	540	N. 86 E.	32	—.27	+.10	+ 7	— 5	4	35 W.
	1877.															
63	Jan. 7.1	13.82	New London	1.60	29.17	29.15	N. 45 E.	228	N. 29 E.	45	—.72	+.10	+27	0	2	30NE.; SW.
64	7.2	11.22	Halifax	1.30	29.23	28.96	N. 75 E.	371	N. 45 E.	41	—.82	+.41	+16	— 2	2	32 W.
65	15.2	12.89	Louisville	1.56	29.39	29.39	S. 87 E.	329	N. 70 E.	44	—.35	+.44	+ 8	—18	3	48 N.
66	Mar. 2.1	13.62	St. Marks	1.81	29.86	29.17	S. 15 E.	755	N. 31 E.	32	—.49	+.10	+11	— 4	6	42 S.
67	2.2	18.52	Charleston	1.40	29.81	29.12	S. 12° E.	810	N. 44 E.	44	—.36	+.24	0	— 9	3	40 S.
68	8.2	14.92	Montgomery	1.58	29.51	29 16	South.	504	N. 72 E.	26	—.41	+.09	0	—28	3	34 S.
69	8.3	11.71	Knoxville	0.90	2 .35	29.07	S. 18 W.	343	N. 57 E.	39	—.24	+.12	+ 8	—12	5	47 S.
70	9.11	21.37	Cape Henry	1.46	29.35	28.87	S. 12 E.	435	N. 51 E.	35	—.48	+.29	+26	—22	6	50 S.
71	26.2	18.44	New London	2.04	29.72	29.34	N. 41 E.	522	N. 69 E.	10	—.10	+.02	+ 1	— 8	2	38 N.
72	Apr. 8.2	12.35	Charleston	3.70	29.46	29.24	S. 59 E.	416	S. 13 E.	4	—.02	+.03	0	— 1	4	36 NE.
73	13.1	12.24	Charleston	5.20	29.40	29.34	N. 70 E.	244	N. 70 E.	36	—.40	+.03	+12	— 8	1	36 NE.
74	19.1	15.67	Dubuque	1.55	29.43	29.26	N. 30 E.	248	N. 82 E.	21	—.05	+.21	0	— 6	5	30 N.
75	19.2	16.97	Milwaukee	1.37	29.57	29.30	N. 14 E.	237	N. 84 E.	26	—.08	+.15	+ 2	—18	3	28 S.; N.
76	28.2	11.46	St. Marks	1.34	29.85	29.40	S. 9 E.	705	N 85 E.	36	—.23	+.13	+15	—16	3	36 N.
77	June 6.3	11.08	New London	2.13	29.80	29.64	N. 46 E.	279	S. 76 E.	12	—.01	+.10	0	—14	5	16 E.; NE.
78	8.2	12.91	Memphis	5.26	29.79	29.59	S. 22 E.	293	N. 56 E.	44	—.13	+.11	0	—18	4	38 N.
79	21.3	14.17	Washington	2.17	29.72	29.53	S. 19 W.	546	N. 47 E.	39	—.12	+.04	0	— 5	2	22 S.
80	July 16.2	14.17	Uvalde, Tex	6.00	29.71	29.48	.....	....	.....	..	.....	.....	....	....	3	30 SW.
81	19.2	14.44	Mt. Washington	2.04	.....	29.50	S. 61 E.	359	N. 64 E.	17	—.04	+.09	+ 1	— 4	6	32 S.
82	Aug. 9.2	12.54	Rio Grande City	2.65	29.95	29.65	.....	....	.....	..	.....	.....	....	....	7	28 SW.
83	Sept. 3.2	12.93	Coleman City	2.74	29.69	29.60	.....	....	.....	..	.....	.....	....	....	3	16 S.
84	5.2	17.22	Pilot Point	3.89	30.04	29.48	.....	....	.....	..	.....	.....	....	....	5	12 NE.
85	7.1	16.67	Norfolk	2.21	29.99	29.95	East.	130	S. 78 E.	20	—.05	+.04	0	— 4	3	34 E.; NE.
86	Oct. 4.2	20.71	Washington	3.69	29.32	29.29	North.	155	N. 52 E.	38	—.29	+.26	+ 6	—22	2	36 SE.
87	4.3	17.87	New York	3.95	29.44	29.36	N. 7 E.	123	N. 7 E.	20	—.18	+.21	+ 6	—20	2	56 NW.
88	9.1	18.80	Barnegat	2.60	30.03	29.89	S. 35 E.	507	N. 79 E.	24	—.09	+.12	+ 6	— 6	6	23 E.
89	14.2	14.85	Pilot Point	4.60	29.96	29.46	.....	....	.....	..	.....	.....	....	....	2	24 E.
90	16.2	23.70	Indianola	3.87	29.87	29.62	.....	....	.....	..	.....	.....	....	....	3	44 NE.
91	17.2	12.32	Fredericksburgh	3.52	29.63	29.51	.....	....	.....	..	.....	....	....	. ..	3	12 N.; W.; SW.; S.
92	19.2	14.49	Chicago	1.67	29.88	29.70	N. 26 E.	248	S. 77 E.	6	—.03	+.02	0	— 7	1	40 NW.
93	30.1	12.61	New Orleans	3.40	29.99	29.84	East.	585	.....	..	.....	.....	....	....	2	48 NE.
94	Nov. 1.2	15.21	Pilot Point	3.06	29.81	29.45	.....	....	.....	..	.....	.....	....	....	1	34 S.
95	2.1	13.27	Knoxville	1.08	29.62	29.11	South.	359	N. 43 E.	41	—.42	+.16	+13	— 6	4	38 SE.
96	2.2	14.23	Sandy Hook	1.19	29.37	29.00	S. 40 E.	689	N. 41 E.	37	—.48	+.31	+ 8	— 6	2	44 SW.
97	8.1	14.50	New Orleans	2.30	29.86	29.64	S. 13 E.	507	N. 64 E.	47	—.20	+.17	+16	— 5	2	40 NW.
98	8.2	26.01	Charleston	3.80	29.79	29.47	S. 36 E.	585	N. 58 E.	36	—.34	+.16	+10	— 8	4	37 SE.
99	8.3	19.31	Mt. Washington	1.98	29.93	29.48	N. 74 E.	546	N. 50 E.	33	—.23	+.20	+18	—14	4	48 N.
100	9.1	20.30	Mt. Washington	2.66	29.85	29.54	East.	218	N. 66 E.	58	—.30	+.24	+19	—13	2	40 N.
101	19.2	21.22	Decatur	2.97	29.79	29.47	.....	....	.....	..	.....	.....	....	....	4	17 E.
102	24.1	16.40	Cape Henry	1.94	29.85	29.66	S. 86 E.	281	N. 11 W.	17	—.06	+.04	+ 3	— 3	1	44 E.
103	Dec. 5.1	12.07	St. Marks	2.15	30.00	29.33	.....	....	.....	..	.....	.....	....	....	2	36 NW.
104	5.2	15.54	Cape Hatteras	1.81	29.97	29.44	S. 33 E.	920	N. 85. E.	33	—.30	+.24	+13	—16	4	36 NW.
105	20.2	14.62	Coleman City	5.13	29.49	29.46	.....	....	.....	..	.....	.....	....	....	2	25 E.
106	29.2	12.48	Wilmington	2.30	29.44	29.37	N. 86 E.	444	N. 41 E.	22	—.15	+.06	÷ 3	— 5	2	40 E.

248. For each of the cases named in Table CXIII the curves of equal rainfall have been accurately drawn upon maps of the United States, and these curves have been carefully compared. Table CXIV shows the geographical extent of some of these rain areas. Column 1 shows the number of reference taken from Table CXIII; column 2 shows in English miles the greatest and least diameters of the area over which the rainfall was at least 1 inch in 8 hours; and column 3 shows the greatest and least diameters of the area over which the rainfall was at least half an inch in 8 hours.

TABLE CXIV.—*Dimensions of remarkable rain areas.*

No.	Area of one inch rain.	Area of half inch rain.	No.	Area of one inch rain.	Area of half inch rain.	No.	Area of one inch rain.	Area of half inch rain.	No.	Area of one inch rain.	Area of half inch rain.
43	811— 89	984—226	25	537—271	680—362	52	456—346	534—468	15	380—296	468—390
44	764—190	833—521	93	500—133	538—164	9	443—167	714—393	51	380—140	437—210
92	733—128	922—231	21	490—188	514—236	8	440—160	858—356	72	379—116	454—156
97	677—168	817—295	90	484—460	500—484	53	418— 67	605—148	64	377—136	443—426
34	629—126	782—211	98	473—140	565—268	73	418—187	597—312	17	374—150	796—340
5	618—111	936—276	102	473—207	543—409	99	412—176	440—260	86	374—296	402—320
4	605—334	668—430	11	470—197	669—304	33	396—200	496—290	41	362—165	847—271
100	565—100	847—307	31	468—162	652—312	71	390—126	449—186	3	360—304	440—402

249. The form of these rain areas is sometimes quite irregular, but generally it approximates to an ellipse of which the major axis is double the minor axis. This elongated form of rain areas is more noticeable in storms which prevail near the Atlantic coast, than it is in regions remote from the ocean. It will be seen that in ten cases the area of 1 inch rainfall was at least 500 miles in length, and in three cases it exceeded 700 miles in length. In eight cases the area of one half-inch rainfall exceeded 800 miles in length. Frequently the entire rain area is an oval figure whose length exceeds 1,000 miles, and whose breadth exceeds 500 miles. Several of these rain areas are represented on the accompanying plates. (See Plates XLVII, Fig. 2; XLVI, Fig. 1; XLII, Fig. 1; XL, Fig. 2; XXXIX, Fig. 2; XXXVIII, Fig. 1; XXXVIII, Fig. 2; XLIV, Fig. 1, etc.)

The distribution by months of the 106 cases shown in Table CXIII, was as follows:

	Cases.		Cases.		Cases.		Cases.
December	11	March	9	June	4	September	9
January	14	April	8	July	5	October	13
February	5	May	2	August	6	November	20
Winter	30	Spring	19	Summer	15	Autumn	42

These great rain areas are thus seen to be least frequent in summer and most frequent in autumn. In article 238 we have found that excessive rains at single stations are most common during the summer months, but very extensive rainfalls are most common in autumn.

The distribution of these 106 cases according to the hour of the day was as follows:

7:35 a. m., 40 cases; 4:35 p. m., 51 cases; 11 p. m., 15 cases.

If we correct these numbers for the inequality of the time intervals, we find that great rainfalls are much less frequent from 4:35 p. m. to 11 p. m. than during the remainder of the day.

The directions of the station of greatest rainfall from the point of minimum pressure were as follows:

	Cases.
In the Southeast quadrant	36
Northeast quadrant	34
Southwest quadrant	9
Northwest quadrant	3
South	4
East	5
North	1
Total	92

We see that the greatest rainfall generally occurred on that side of the center of low pressure towards which the low area was advancing; that is, the low center moved towards the rain area. In about 60 per cent. of the whole number of cases, these two directions were inclined to each other less than 60°. This coincidence would have been more frequent if the direction of progress of the low center had been compared with the direction of the greatest rain area instead of the station of greatest rainfall; for frequently the station of greatest rainfall was not included in the greatest rain area. In several of the cases in which the principal rain center was on the west side of the low center, the geographical extent of the rain areas on the east side was greater than that on the west side. This was true of Nos. 7, 10, and 46. This fact seems to indicate that the general movement of the winds depends more upon the geographical extent of rain areas than upon the quantity of rain which falls at a single station. It will also be noticed that in two cases (Nos. 26 and 27), when the rain center was in the northwest quadrant, the center of least pressure moved towards the northwest, which appears to indicate very distinctly the tendency of a low center to incline towards a rain area.

Of the remaining six cases (Nos. 13, 38, 40, 56, 69, and 79), in which the station of greatest rainfall was southwest of the center of minimum pressure, the rainfall on the southwest side accompanied the advance of an area of high pressure, with winds from the northwest quarter supplanting the southerly winds which had preceded. Plate XXXIX, Fig. 1 (June 21, 1877, 11 p. m.), affords an example of this species of movement. The barometric gradients within the rain area were small, and the rainfall in the southwest quadrant had but little influence in determining the general movement of the winds about the low center because the southerly winds were soon supplanted by the advancing west and northwest winds.

In 1874, January 22.1 (Pl. XLVIII, Fig. 2), the isobars were very much elongated from southwest to northeast and there were three centers of maximum rainfall. About two of these rain centers the cyclonic movement of the winds was distinctly marked. The low center was carried forward by the north and west winds which followed it on its western side. In 1877, March 8.2 (Pl. XLIV, Fig. 2), the rain areas as well as the isobars were very much elongated from southwest to northeast and the great rainfall on the south side of the low center apparently resulted from the uprising of the southerly winds upon the front side of the storm, aided by the northerly winds which followed the southerly winds and pushed under them.

In three-quarters of the whole number of cases shown in Table CXIII, the rain center was distant from the low center less than 500 miles. The rain center was distant from the low center

More than 500 miles, in 27 cases.
600 miles, in 13 cases.
700 miles, in 8 cases.
800 miles, in 3 cases.
900 miles, in 1 case.

When the rain center was very remote from the principal low center, the winds were sometimes controlled by a smaller low center in its immediate vicinity, and after a few hours the two low centers coalesced. Such was the case with No. 5 (November 7.1, 1872, Pl. XXXVIII, Fig. 1). In other cases, however, the winds appeared to be mainly controlled by a center of low pressure distant more than 700 miles, but in a majority of these cases the principal rain center was south of latitude 36°.

250. There is generally a marked uniformity in the changes of pressure and temperature accompanying the eastward progress of an area of low pressure. In front of the low area the pressure diminishes, and in the rear the pressure increases. For the cases in Table CXIII, the average diminution of pressure in 8 hours on the front side of the storm was 0.24 inch, and the average increase of pressure on the rear side was 0.12 inch. For different storms, however, these numbers were very unequal. In seven of the cases in Table CXIII, in front of the storm the barometer fell more than half an inch in 8 hours, and in one case (at Eastport, Me., January 7.2, 1877) in 8 hours the barometer fell 0.86 inch. On the other hand, there were several cases in which the barometer remained nearly stationary for the 8 hours preceding the approach of the low center. There were four cases in which the rise of the barometer in the rear of the storm exceeded 0.40 inch in 8 hours. There were several cases in which in the rear of the storm the barometer was almost entirely

stationery for 8 hours, and there were two cases in which during the 8 hours succeeding the passage of the storm's center, there was an averaged iminution of pressure amounting to four or five hundredths of an inch. These cases in which the pressure remained nearly stationary for 8 hours preceding or following the low center, generally resulted from the interference of a second area of low pressure. When an area of low pressure is preceded by a second area of low pressure within a distance of a few hundred miles the fall of the barometer in front of the first low center is generally very small; and when an area of low pressure is followed immediately by a second area of low pressure the rise of the barometer in the rear of the first low center is generally very small.

For the cases in Table CXIII, during the 24 hours preceding the approach of the low center, there was an average rise of the thermometer amounting to 7°; and during the succeeding 24 hours there was an average fall of 8°; but these numbers fluctuated from 28° to zero, over a large geographical area, and in individual cases the fluctuations were considerably greater. In a few cases there was a noticeable correspondence between the magitude of the barometeric and thermometric fluctuations attending the progress of a low center, but generally such a correspondence was not very distinctly marked, the changes of temperature being often due to causes which had but little influence upon the barometer.

251. Table CXIII shows that in the United States a single rain area seldom occurs alone. Out of 106 cases there were only 11 in which there was but one rain area with at least a half-inch rainfall; and if the comparison had included all cases of a quarter-inch rainfall, the number of cases of but one rain area would have been still less. The accompanying plates represent 15 cases with at least two centers of rainfall exceeding a quarter-inch; 8 cases with at least three centers of rainfall exceeding a quarter-inch; and 4 cases with four centers of rainfall exceeding a quarter-inch. If the plates had included the entire area of the United States, east of the Rocky Mountains, more rain centers would have been represented. Plate XL, Fig. 1, would have exhibited eight rain centers, five of which exceed a half-inch. In 1872, September 11.3, there were eight rain centers, all of which exceed a half-inch. These facts suggest the idea that those conditions which are favorable to rainfall at one locality are generally favorable to rainfall over a much larger district, and hence there often results a simultaneous precipitation at several points remote from each other. Extensive rains frequently appear to result from an unstable condition of the atmosphere, in consequence of which the stratum of air near the earth's surface tends to ascend. This unstable condition may result from a temperature above the mean for the given time and place, and it may also result from the presence of an unusual amount of aqueous vapor. We have found that on the east side of an area of low pressure the temperature is generally above the mean; and the presence of an unusual amount of vapor in the air affords a very reliable basis for anticipating the approach of rain. These conditions of unusual heat and unusual humidity often prevail simultaneously over an area several hundred miles in diameter. Over such a region the entire stratum of air near the earth's surface tends to ascend. A general ascent of the air over a large area is impossible, but some local cause may determine an upward movement at some point in this area, and the surrounding air will be drawn in to supply the place of the air which ascends. The vapor of the ascending air will be cooled by elevation, and be precipitated, and thus may commence a shower, which under favorable conditions will increase and continue for several hours. When this unstable condition of the air prevails over a large area, there may be more than one point where such an ascending current is formed, and thus we may have several rain areas prevailing simultaneously within a few hundred miles of each other. Near each of these rain centers the tendency of the air is toward the rain area, and by the earth's rotation the pressure over the rain area is diminished. To exhibit these effects in the clearest manner requires that the stations of observation should be numerous and very close together, but some of the accompanying plates are tolerably satisfactory. Plate XLI, Figs. 1 and 2 (1874, September 28.1, and 1877, April 13.1), exhibit an extraordinary rainfall, and an extraordinary fall of the barometer accompanying a cyclonic movement of the winds. A similar cyclonic movement of the winds is less distinctly indicated on Plate XL, Fig. 1 (1873, July 27.2), near Washington, New York, and Nashville. The depression of the barometer caused by local disturbances is generally only a few hundredths of an inch; and after a few hours such a disturbance is usually absorbed by a more general disturbance whose center is distant only a few hundred miles.

The last column of Table CXIII shows that great rain areas are usually attended by high winds. In a majority of the cases, at some point within the low area attending these rains, the velocity of the wind exceeded 30 miles an hour. These high winds do not come with equal frequency from all points of the compass. The number of cases for the different winds was as follows:

	Cases.		Cases.
Wind from the north	19	Wind from the south	19
northeast	26	southwest	8
east	20	west	7
southeast	11	northwest	14

The highest winds are seen to come most frequently from the northeast and east; and they come least frequently from the west and southwest. It might be supposed that these strong easterly winds would overcome the feebler westerly winds, and that the storm would advance towards the west. But in fact these easterly winds before reaching the storm center ascend and cease to be surface winds. In the storm of 1877, April 13.1 (Plate XLI, Fig. 2), the wind at Charleston blew from the northeast at the rate of 36 miles per hour, while the wind at Savannah blew from the southwest at the rate of 18 miles per hour. The easterly winds ascended to a considerable height, so that their vapor was condensed, causing the extraordinary rainfall of 5.20 inches in 8 hours at Charleston.

252. In order to determine the average duration of great rainfalls I selected all those cases in which any of the rainfalls enumerated in Table CXIII, for the years 1872 and 1873, were followed by at least 6 inches of rain (total amount at all the stations east of the Rocky Mountains) during a succeeding period of 8 hours; and for the years 1874 and 1877 I selected all those cases which were followed by at least 7 inches of rain during the next 8 hours. Table CXV shows the result of this comparison. Columns 2, 3, and 4 are taken from Table CXIII; columns 5, 6, and 7 and the remaining columns furnish similar information for the succeeding period of 8 hours.

We thus see that in a period of 41 months there were 45 cases in which some one of the rainfalls of Table CXIII was followed by a total rainfall of more than 6 inches in the next 8 hours in 1872 and 1873, and by more than 7 inches in the next 8 hours in 1874 and 1877; there were 26 cases in which it was followed by a similar rainfall for a third period of 8 hours; there were 16 cases of a fourth period of 8 hours, and 2 cases of a fifth period of 8 hours. These rain areas which succeeded each other in order of time were not, however, in all cases apparently connected with each other; that is, they were not continuous rain areas or even adjacent to each other. Those cases which were apparently thus connected are indicated by the numerals 1, 2, 3, etc., attached to the names of the stations. It must not be inferred that these rain areas had in all cases a proper movement of translation in the direction of the stations here indicated. In some cases this apparent movement resulted from a slight increase of precipitation in one part of an extensive rain area and a decrease in some other part.

Table CXV shows that great rain areas are seldom of long continuance. In 37 cases the same rain area continued for at least two periods of 8 hours; in 12 cases it continued for at least three periods; and in 5 cases it continued for four periods, that is, for 32 hours; but there is no case of a great rain area continuing for a fifth period of 8 hours. We thus see that rain areas with a total rainfall of 6 or 7 inches in 8 hours for all the stations east of the Rocky Mountains seldom continue for more than 24 hours, only 5 such cases having been found in a period of 41 months. These facts seem to indicate that the causes which produce rain do not derive increased force from the rainfall for an indefinite period of time, but after a few hours they expend themselves and become exhausted.

TABLE CXV.—*Heavy rainfall continuing more than 8 hours.*

No.	Date.	Total rain.	Station of greatest rain.	Date.	Total rain.	Station of greatest rain.	Date.	Total rain.	Station of greatest rain.	Date.	Total rain.	Station of greatest rain.
1	'72. Nov. 6.3	9.91	Montgomery ..	Nov. 7.1	13.52	New York[1]	Nov. 7.2	6.27	New London[2]			
2	'73. Jan. 2.2	9.12	Keokuk	Jan. 2.3	6.37	Port Stanley[1]	Jan. 3.1	8.63	New York[2]			
3	5.1	12.02	Lake City	5.2	16.16	Philadelphia						
4	16.1	10.08	New Orleans ..	16.2	6.23	Detroit						
5	Feb. 16.1	10.54	Louisville[1]	Feb. 16.2	9.60	Cape May[2]						
6	Mar. 29.1	10.52	Lake City	Mar. 29.2	10.42	Oswego						
7	May 1.2	9.37	Montgomery ..	May 1.3	7.95	New Orleans	May 2.1	11.74	Wilmington[1]	May 2.2	8.49	Wilmington.[3]
8	July 27.2	9.63	Washington[1] ..	July 27.3	7.31	Philadelphia[2]						
9	Aug. 13.1	9.52	Philadelphia[1] ..	Aug. 13.2	8.27	Philadelphia[2]	Aug. 13.3	7.81	Baltimore[3]	Aug. 14.1	7.42	Breckenridge.
10	21.1	9.56	Galveston[1]	21.2	7.06	Mobile[2]						
11	Sept. 19.2	11.37	Cape May[1]	Sept. 19.3	8.96	Mt. Washington[2] ..	Sept. 20.1	6.32	Wilmington			
12	Oct. 19.3	9.82	New London[1] ..	Oct. 20.1	17.65	Philadelphia[2]	Oct. 20.2	12.27	Rochester[3]	Oct. 20.3	9.86	Buffalo.[4]
13	Nov. 24.1	11.16	Nashville	Nov. 24.2	14.69	New London				[Dec. 13.2]	6.77	Boston.
14	Dec. 3.1	10.65	St. Louis[1]	Dec. 3.2	10.02	Indianapolis[2]	Dec. 3.3	14.70	Louisville[3]	4.1	8.47	Knoxville.[4]
15	12.1	10.51	Cleveland[1]	Dec. 12.2	7.01	Cincinnati[2]	12.3	6.69	Louisville[3]	13.1	6.55	Mobile.
16	'74. Jan. 6.2	12.55	Wilmington[1] ..	Jan. 6.3	8.37	Lynchburg[2]	Jan. 7.1	11.81	Wilmington[3]	Jan. 7.2	9.69	New York.[4]
17	22.1	10.20	St. Louis[1]	22.2	8.30	Cairo[2]						
18	Feb. 13.1	10.12	Cairo[1]	Feb. 13.2	7.70	Louisville[2]	Feb. 13.3	9.45	Baltimore	Feb. 14.1	7.32	Savannah.
19	April 19.2	14.61	Vicksburg[1]	April 19.3	9.31	Cincinnati[2]	April 20.1	14.36	Milwaukee	April 20.2	9.38	New London.
20	July 4.2	10.22	New Orleans[1] ..	July 4.3	9.77	New Orleans[2]						
21	Aug. 8.1	10.58	New London[1] ..	Aug. 8.2	11.42	New London[2]	Aug. 8.3	9.23	New London[3]	Aug. 9.1	7.29	Boston.[4]
22	Sept. 18.3	10.27	Dubuque[1]	Sept. 19.1	9.53	Duluth[2]	Sept. 19,2	7.51	Duluth[3]			
23	28.1	13.01	Savannah[1]	28.2	7.42	Charleston[2]						
24	Nov. 22.3	13.22	Cincinnati	Nov. 23.1	21.40	Barnegat[1]	Nov. 23.2	13.04	Portland, Me[2]			
25	29 1	10.75	Washington[1] ..	29.2	13.31	Eastport[2]						
26	'75. Jan. 2.1	13.98	Knoxville	Jan. 2.2	7.59	New London						
27	'77. Jan. 7.1	13.82	New London[1] ..	7.2	11.22	Halifax[2]						
28	15.2	12.89	Louisville	15.3	8.23	Milwaukee	Jan. 16.1	9.81	Mt. Washington ..			
29	Mar. 2.1	13.62	St. Marks[1]	Mar. 2.2	18.52	Charleston[2]	Mar. 2.3	7.18	Portland, Me			
30	8.2	14.92	Montgomery[1] ..	8.3	11.71	Knoxville[2]	9.1	21.37	Cape Henry[1]	Mar. 9.2	7.48	Boston.[3]
31	26.2	18.44	New London[1] ..	26.3	9.30	New London[2]	27.1	8.40	Mt. Washington[3]			
32	April 13.1	12.24	Charleston[1] ...	April 13.2	9.10	Charleston[2]						
33	19.1	15.67	Dubuque[1]	19.2	16.97	Milwaukee[2]	April 19.3	9.25	Washington	April 20.1	8.55	Lynchburgh.
34	28.2	11.46	St. Marks	28.3	7.04	Pittsburgh						
35	June 6.3	11.08	New London[1] ..	June 7.1	8.24	New London[2]						
36	8.2	12.91	Memphis	8.3	10.39	Corsicana	June 9.1	9.99	Memphis	June 9.2	8.97	Port Huron.
37	Sept. 7.1	16.67	Norfolk[1]	Sept. 7.2	7.75	Cape Lookout[2]						
38	Oct. 4.2	20.71	Washington[1] ..	Oct. 4.3	17.87	New York[2]	Oct. 5.1	11.21	Boston[3]			
39	9.1	18.80	Barnegat[1]	9.2	7.60	Albany[2]						
40	19.2	14.49	Chicago[1]	19.3	9.60	Sandusky[2]	Oct. 20.1	8.84	Toledo[3]			
41	Nov. 1.2	15.21	Pilot Point[1] ...	Nov. 1.3	10.57	Vicksburg[2]	Nov. 2.1	13.27	Knoxville[3]	Nov. 2.2	14.23	Sandy Hook.
42	8.1	14.50	New Orleans ..	8.2	26.01	Charleston	8.3	19.31	Mt. Washington[1] ..	9.1	20.30	Mt. Washington.[2]
43	24.1	16.40	Cape Henry[1] ..	24.2	10.36	Cape May[2]				[Nov. 9.2]	7.67	Key West.
44	Dec. 5.1	12.07	St, Marks	Dec. 5.2	15.54	Cape Hatteras	Dec. 5.3	10.81	Mt. Washington[1] ..	Dec. 6.1	10.84	Mt. Washington.[2]
45	29.2	12.48	Wilmington[1] ..	29.3	7.96	Cape Lookout[2]	30.1	7.10	Cape Henry[3]	30.2	7.96	Cape May.[4]

253. Although considerable rain attends all great storms or areas of very low barometer, and these areas of low barometer can sometimes be traced through a distance of several thousand miles, yet the rainfall in such a storm does not form a regular rain belt of nearly uniform breadth but rather a succession of rain areas grouped irregularly together. The continuity of the belt may not be absolutely broken, but its breadth and density exhibit great irregularities. While a storm is pursuing its path from the Rocky Mountains to the Atlantic Ocean the breadth of the rain belt may vary from 100 or 200 miles to 1,500 miles, and the amount of rain near the central line of the belt may vary from 4 or 5 inches to less than one-tenth of an inch. This peculiarity of the rainfall is distinctly indicated by the rain charts issued monthly by the Signal Service. We find no indications of belts of rain of uniform breadth stretching across the continent, but rather a promiscuous collection of rain areas of irregular form and of unequal magnitude.

In order to investigate this subject more fully I have determined for each of the cases in Table CXV the total rainfall at each of the stations during the period when it was included within the low area under investigation. Table CXVI shows the total amount of rainfall at each of the stations for No. 14 during the five days from December 1 to 5, 1873, counting only the rain which fell within the low area; that is, while the barometer was below 30 inches. At Mobile, Montgomery, and several other southern stations some rain fell during this period when the barometer was above 30 inches, but this rain is not included in Table CXVI.

TABLE CXVI.—*Rainfall from December* 1 *to* 5, 1873.

Station.	Rain.	Station.	Rain.	Station.	Rain.	Station.	Rain.	Station.	Rain.
Alpena	0.26	Davenport	1.21	Indianapolis	3.46	Montreal	0.37	Quebec	1.34
Augusta	.00	Denver	.37	Indianola	.00	Mt. Washington	.09	Rochester	.26
Baltimore	.01	Detroit	1.73	Jacksonville	.00	Nashville	1.90	Santa Fé	.01
Boston	.10	Dubuque	.70	Keokuk	.98	New London	.08	Saugeen	.55
Breckenridge.	.11	Duluth	.15	Kingston	.95	New Orleans	.00	Savannah	.00
Buffalo	.64	Eastport	.15	Knoxville	1.66	New York	.01	Shreveport	1.41
Burlington	.00	Erie	.41	La Crosse	.86	Norfolk	.00	St. Louis	2.68
Cairo	1.25	Escanaba	1.12	Lake City	.00	Omaha	.08	St. Paul	.13
Cape May	.00	Father Point.	.12	Leavenworth	.77	Oswego	.49	Sydney	.00
Cape Rozier	.05	Fort Benton	.00	Louisville	2.30	Pembina	.13	Toledo	2.07
Charleston	.00	Fort Garry	.29	Lynchburgh	.06	Philadelphia	.11	Toronto	.26
Chatham	.01	Fort Gibson	.57	Marquette	.55	Pittsburgh	.42	Vicksburg	.03
Cheyenne	.05	Fort Sully	.00	Memphis	.69	Port Dover	.81	Virginia City.	.00
Chicago	1.20	Galveston	.02	Milwaukee	1.09	Port Stanley	.92	Washington	.01
Cincinnati	2.47	Grand Haven.	.44	Mobile	.00	Portland	.00	Wilmington	.00
Cleveland	.64	Halifax	.17	Montgomery	.00	Punta Rassa	.00	Yankton	.12

The numbers in this table are represented by curves on Plate L, which shows the boundary of the area having a total rainfall of one-tenth of an inch; also the area of a half-inch rainfall, of 1 inch rainfall, of 2 inches and 3 inches. We see that west of the meridian of 98° from Greenwich, the aggregate rainfall for these five days was less than one-tenth of an inch; and as the low center advanced eastward the rainfall rapidly increased up to 3.46 inches at Indianapolis; after which it declined with almost equal rapidity, and in longitude 67° became reduced to one-tenth of an inch. The dotted line shows the course of the center of low pressure, its position at the date of each observation being indicated by the figures, 2.1, 2.2, 2.3, 3.1, etc. During the progress of this storm the pressure at the center of the low area underwent great changes. Table CXVII shows the lowest pressures reported at any of the stations for each of the dates from December 2.1 to 5.1.

We see that the pressure at the center of the low area decreased until December 4, at $7\frac{1}{2}$ a. m., and this was more than 8 hours after the time when the rainfall had reached its maximum; also, we see that the pressure slowly increased as the amount of rainfall decreased. These facts appear to illustrate the inertia of the atmosphere, the minimum of pressure having occurred considerably later than the maximum of rainfall, and when the rainfall had apparently well nigh ceased the pressure was only partially restored.

TABLE CXVII.—*Lowest barometer from December 2.1 to 5.1, 1873.*

Date.	Bar.	Station.	Date.	Bar.	Station.	Date	Bar.	Station.	Date.	Bar.	Station.
Dec. 2.1	29.65	Denver.	Dec. 3.1	29.54	Escanaba.	Dec. 4.1	28.91	Marquette.	Dec. 5.1	29.65	Cape Rozier.
2.2	.55	Leavenworth	3.2	.37	Chicago.	4.2	29.43	Quebec.	.....	.....	.....
2.3	.52	Dubuque.	3.3	.08	Escanaba.	4.3	.29	Chatham.	.....	.....	.....

254. The results obtained in this case accord substantially with those found in a large number of other cases. In all of the cases shown in Table CXV, the rainfall west of the meridian of 100° was well nigh inappreciable, and the rainfall increased rapidly as the low area moved eastward. Whenever there was a heavy rainfall west of the meridian of 85°, the rain almost invariably declined before reaching the Atlantic coast. The heavy rainfalls near the Atlantic coast generally commence in the south near the Gulf of Mexico and follow the Atlantic coast toward the northeast.

The decrease in the rainfall in the case of No. 14 was apparently caused by a very cold westerly wind, which followed the low area and attained in many places a velocity of 40 miles per hour, and in one place a velocity of 49 miles per hour. In Table CXVIII, column 2 shows the diminution of temperature in 24 hours at various stations during the progress of this storm; and it should be remembered that these changes were independent of the ordinary diurnal variation of temperature. These numbers are considerably larger than those given in column 15 of Table CXIII, those numbers being designed to represent the average change of temperature over a large area in the rear of the storm.

TABLE CXVIII.—*Fall of temperature in twenty-four hours, December 2–5, 1873.*

Date.	Ther.	Station.	Date.	Ther.	Station.	Date.	Ther.	Station.	Date.	Ther.	Station.
	°			°			°			°	
Dec. 2.3	32	Cheyenne.	Dec. 3.3	39	Davenport.	Dec. 4.1	31	Memphis.	Dec. 4.3	30	Indianapolis.
	37	Denver.		40	Ft. Gibson.		43	Milwaukee.		35	Pittsburgh.
	36	Leavenworth.		36	St. Louis.		30	Nashville.	Dec. 5.1	31	Oswego.
	31	Virginia City.	Dec. 4.1	39	Cairo.		41	St. Louis.		37	Rochester.
Dec. 3.1	37	Leavenworth.		40	Chicago.	Dec. 4.2	33	Louisville.		33	Mt. Washington.
3.2	36	Keokuk.		31	Dubuque.		36	Memphis.	Dec. 5.2	30	Norfolk.
	35	Leavenworth.		50	Indianapolis.		32	Nashville.		32	Washington.
	40	Ft. Gibson.		34	La Crosse.	Dec. 4.3	32	Detroit.			
Dec. 3.3	42	Dubuque.		31	Louisville.		35	Erie.			

In article 251 it was shown that in great rain storms the easterly winds are generally stronger than the westerly winds. In the case of No. 14 the westerly winds were much the strongest, and during the progress of the storm the velocity of the easterly winds diminished while the westerly winds increased in force. After the morning of December 4 the rain ceased almost entirely; the south winds on the front of the storm had mostly disappeared, and were succeeded by cold winds of the west or southwest.

255. The preceding examination of the great rainstorms of the United States seems to warrant some generalization respecting the causes of rainfall, or the conditions favorable for rainfall.

A. One of the most common causes of rain is an unstable condition of the atmosphere resulting from an unusually high temperature combined with unusual humidity. This condition of the atmosphere is most frequently found where the barometric pressure is somewhat below the mean, although it sometimes extends beyond the isobar of 30 inches. It is most frequently found in the eastern segment of the low area, and is generally accompanied by easterly or southerly winds.

B. Another very common cause of rain, and one which is frequently associated with the former, is a cold northerly or westerly wind in the western segment of the low area. This cold wind pushes under the warm and humid wind which prevails in the eastern semicircle of the low area, and lifts it up from the earth's surface to such a height that a considerable portion of its vapor is condensed (see article 244). Several of the accompanying plates exhibit the operation of this cause,

particularly Plate XLIV, Fig. 1 (1873, October 20.1), and Plate XLIV, Fig. 2 (1877, March 8.2). In many of these cases there is direct evidence that the westerly winds in the rear of the storm were merely surface winds, and that the southeast winds which prevailed in front of the storm extended to the rear occupying a stratum of considerable elevation. It is generally difficult and sometimes impossible to obtain evidence of the direction of the upper stratum of air while a rainstorm is prevailing at the surface of the earth; but occasionally there are breaks in the lower stratum of clouds which enable us to observe the movement of the upper clouds. The following examples are derived from the published observations of the Signal Service.

Date.	Station.	Surface wind.	Upper clouds.	Date.	Station.	Surface wind.	Upper clouds.
1873. Oct. 20.1	Detroit	N. 12	S.	1874. April 8.2	Montgomery	N. 7	S.
	Louisville	N. 16	S.	Sept. 16.2	Albany	N. 5	S. E.
	Toledo	N. 15	S. E.				

256. The observations on Mount Washington afford us at all times the means of comparing the winds at low stations with the winds at the height of 6,000 feet. We frequently find the latter winds are from the south or southeast while the surface winds are from the north or west. The following are examples of this kind.

Date.	Mountain.	Base.	Date.	Mountain.	Base.	Date.	Mountain.	Base.
1872. Dec. 9.3	SE. 16	NW. 15	1873. Nov. 18.2	SE. 5	N. 20	1877. Mar. 28.1	SE. 54	N. 13
26.3	S. 5	N. 17	1874. Jan. 14.1	SE. 34	N. 16	28.2	SE. 24	NW. 35
1873. Feb. 22.2	SE. 36	NW. 12	April 20.3	S. 36	N. 13	June 6.3	S. 15	NW. 6
Mar. 4.1	SE. 48	N. 10	28.2	SE. 2	N. 5	7.1	SE. 30	NE. 11
21.1	SE. 50	NE. 28	1877. Mar. 14.1	S. 12	N. 15	Oct. 21.2	SE. 9	NE. 16
31.2	S. 24	N. 11	27.2	SE. 60	N. 10	Nov. 10.2	SE. 9	N. 6
April 26.1	SE. 10	NW. 8	27.3	SE. 66	N. 6			

The example of March 28, 1877, affords a most decisive illustration of the principle above stated. While there was a general movement of the surface winds from the north the wind on Mount Washington blew from the southeast with a velocity of 60 miles per hour, accompanied by an extraordinary fall of rain amounting to 5.29 inches in 24 hours.

C. Proximity to the ocean or to a large inland sea is favorable to rainfall. We have seen (article 240) that heavy rains are more frequent near the coast of the Atlantic Ocean and the Gulf of Mexico than they are at interior stations.

The preceding investigation, taken in connection with the facts stated in Chapter I, affords important evidence respecting the influence of rainfall upon areas of low pressure. The following facts seem well established.

D. *No great barometric depression with steep gradients ever occurs without considerable rainfall.* Table III, in Chapter I, shows that the West India cyclones are always accompanied by heavy rain. Table VII shows that the same is true of cyclones near the China Sea and Bay of Bengal; and Table VIII shows the same for the cyclones of India. Table CXII shows that great barometric depressions in the United States are invariably accompanied by a liberal rainfall.

TABLE CXIX.—*Influence of rainfall on barometric pressure.*

No. 1.	Rain.	Bar.	No. 12.	Rain.	Bar.	No. 14.	Rain.	Bar.	No. 16.	Rain.	Bar.
	Inches.			*Inches.*			*Inches.*			*Inches.*	
'72. Nov. 6.1	5.61	29.73	'73. Oct. 19.1	3.43	29.79	'73. Dec. 2.1	2.86	29.66	'74. Jan. 5.3	3.05	29.95
6.2	7.46	.48	19.2	6.84	.64	2.2	5.60	.55	6.1	8.82	.90
6.3	9.91	.47	19.3	9.82	.52	2.3	2.88	.52	6.2	12.55	.74
7.1	13.52	.33	20.1	17.65	.45	3.1	10.49	.54	6.3	8.37	.61
7.2	6.27	.12	20.2	12.27	.26	3.2	10.02	.37	7.1	11.81	.57
7.3	2.29	.13	20.3	9.86	.30	3.3	14.30	.08	7.2	9.48	.46
8.1	5.99	.07	21.1	5.90	.28	4.1	7.00	28.91	7.3	6.27	.48
8.2	3.61	.19	21.2	2.98	.36	4.2	1.30	29.43	8.1	5.65	.32
8.3	1.56	.33	21.3	2.75	.42	4.3	0.81	.29	8.2	1.68	.31
9.1	6.52	.49	22.1	0.71	.61	5.1	1.35	.65	8.3	0.90	.38
			22.2	0.81	.62				9.1	2.06	.39
No. 22.			No. 23.			No. 24.			No. 27.		
'74. Sept. 17.3	4.49	29.75	'74. Sept. 27.3	3.64	29.72	'74. Nov. 22.1	3.77	29.21	'77. Jan. 5.2	0.96	29.90
18.1	5.94	.69	28.1	13.01	.42	22.2	7.47	.04	5.3	1.47	.89
18.2	7.94	.49	28.2	7.25	.24	22.3	13.22	28.82	6.1	3.41	.84
18.3	10.26	.60	28.3	2.37	.42	23.1	21.40	.75	6.2	6.13	.68
19.1	9.53	.44	29.1	2.75	.41	23.2	13.05	.93	6.3	4.36	.50
19.2	6.74	.26	29.2	5.19	.39	23.3	4.47	.87	7.1	13.73	.15
19.3	2.90	.62	39.3	5.18	.24	24.1	4.58	.89	7.2	10.80	28.96
20.1	3.75	.85	30.1	7.37	.05	24.2	1.03	.91	7.3	2.59	29.05
20.2	3.68	.88	30.2	2.35	28.94	24.3	0.90	29.04	8.1	3.18	.21
			30.3	0.26	29.20	25.1	0.80	.37			
No. 28.			No. 29.			No. 30.			No. 32.		
'77. Jan. 13.3	0.66	29.87	'77. Feb. 28.2	0.98	29.90	'77. Mar. 6.3	1.26	29.91	'77. Apr. 11.2	0.05	29.72
14.1	1.29	.76	28.3	2.15	.88	7.1	1.46	.76	11.3	0.55	.70
14.2	0.48	.67	Mar. 1.1	4.15	.73	7.2	1.88	.55	12.1	5.27	.59
14.3	1.82	.57	1.2	9.21	.56	7.3	2.81	.54	12.2	6.68	.51
15.1	8.06	.45	1.3	5.11	.42	8.1	8.43	.45	12.3	4.65	.52
15.2	12.79	.39	2.1	13.62	.17	8.2	14.82	.16	13.1	12.24	.34
15.3	8.70	.37	2.2	18.52	.07	8.3	11.47	.07	13.2	9.10	.30
16.1	9.57	.56	2.3	6.73	.24	9.1	20.48	28.87	13.3	6.95	.41
16.2	2.86	.81	3.1	4.16	.29	9.2	6.93	.74	14.1	4.51	.39
			3.2	3.80	.63	9.3	1.47	29.22	14.2	0.65	.70

E. In great rainstorms the *barometric pressure generally diminishes, while the rainfall increases.* It is easy to find in the Signal Service observations illustrations of this principle embracing a period of one or two days; but if we wish to compare the changes of barometric pressure with the changes in the rainfall for a period of 3 days or more, we generally find that the geographical extent of the United States, east of the Rocky Mountains, is too small for a satisfactory comparison. In great rainstorms the barometric pressure generally diminishes steadily until the low center reaches the Atlantic coast, and the rainy segment of the low area passes over the ocean from which we receive no observations of the amount of the rainfall. Moreover a second area of low pressure sometimes interferes with the first and renders the results very complicated. The effects may also be complicated by local causes, or by the interference of neighboring areas of high pressure. Table CXIX shows twelve cases derived from Table CXV, in which the relation of barometric pressure to rainfall is exhibited without being greatly complicated by the causes above named. The table shows the lowest observed pressure for the given dates, and also the total rainfall at all the stations east of the Rocky Mountains.

In ten of these cases the barometric pressure diminished as long as the rainfall increased. There are two cases which may be claimed as exceptions to this rule, viz, Nos. 22 and 23. The slight increase of pressure in No. 22, September 18.3, 1874, was apparently due to cold winds which pressed in with great force from the northwest; and the sudden fall of the barometer in No. 23, September 28.2, 1874, was due to an extraordinary rainfall at Savannah, which had but a small geographical extent, and had only a diminished effect on the pressure of succeeding days.

F. *The greatest depression of the barometer generally occurs about* 12 *hours after the greatest rainfall.* Table CXIX shows two cases in which the least pressure and the greatest rainfall

occurred simultaneously. In one case the least pressure was 48 hours later than the greatest rainfall; in one case it was 24 hours later; in one case it was 16 hours later, and in six cases it was 8 hours later. In one case (No. 23) the least pressure occurred 56 hours after the greatest rainfall; but if we neglect the effect ascribed to the great rainfall at Savannah, the retardation was only 8 hours. The average of all these numbers is 12 hours.

G. A great fall of rain is favorable to a rapid progress of the center of least pressure, while a small rainfall is generally attended by a less rapid progress. This fact is indicated by Tables XXX and XXXI of Chapter I, where we have found that when a barometric minimum advances 1,000 miles in 24 hours, the average rainfall for a period of 8 hours at all the stations within the low area on the east side of the low center is 0.16 inch, and on the west side it is 0.06 inch; but when the barometric minimum advances less than 240 miles in 24 hours, the average rainfall for 8 hours on the east side of the low center is only 0.09 inch, and on the west side 0.03 inch.

The same fact is indicated by column 11, of Table CXIII, which shows that when there is a great rainfall the average rate of progress of the low center is a little greater than the general average of low areas as shown in Table XXIX. Since, however, the velocities given in Table CXIII are very unequal, it is plain that the rate of progress of a low center depends partly upon other causes than the amount of rainfall. These results accord with those stated in Chapter I, article 77.

Areas of low pressure without rain.

257. In order to compare the influence of a very small rainfall with that of a very great rainfall, I selected from the published volumes of the Signal Service observations all those cases in which the total rainfall at all the stations east of the Rocky Mountains was less than one-tenth of an inch in 8 hours. Table CXX exhibits these cases. Column 1 contains the number of reference; column 2 shows the day and hour of observation; column 3 shows the total rainfall for the preceding 8 hours at all the stations. In September, 1872, the number of stations east of the Rocky Mountains was 65. This number steadily increased from year to year, and in December, 1877, amounted to 114. Column 4 shows the least height of the barometer, and column 5 shows the station at which the pressure, given in column 4, was observed. Sometimes the same map showed two low centers, one near the Atlantic coast, and another in the western part of the United States. In such cases the Table shows only the western low center. Column 6 shows the direction in which the low center had moved during the last 8 hours; and column 7 shows the velocity with which it moved expressed in miles per hour. In consequence of the feeble gradients and the small number of stations in the vicinity of the low center, it was frequently impossible to form any reliable estimate of the velocity of progress, or even the direction of movement of the low center. An asterisk (*) in column 6 indicates that the low center had apparently remained stationary during the preceding 8 hours. Column 8 shows the total amount of rain observed within the area of low barometer; that is, at the stations where the pressure was less than 30 inches. Generally within the low area there was a region of considerable extent where the temperature was above the average for the given time and place. Column 9 shows how much the thermometer rose above the normal at any of the stations; and column 10 shows the station at which this temperature was observed. Column 11 shows the relative humidity at the station named in the preceding column; column 12 shows the velocity of the wind, and column 13 shows the degree of cloudiness (expressed in fourths of the visible heavens). Column 14 shows the height of the barometer at the center of maximum pressure, and column 15 shows the station at which this high pressure was observed.

TABLE CXX.—*Total rainfall at all stations east of the Rocky Mountains, less than one-tenth of an inch in eight hours.*

No.	Date.	Total rain.	Low bar.	Station.	Low moved.		Rain in low.	Thermometer.		Humidity.	Wind vel.	Cloud.	High bar.	Station.
					Direction.	Vel.		Above normal.	Station.					
	1872.							°						
1	Sept. 2.3	0.04	29.65	Fort Sully.....	*	0	0.00	+22	Fort Sully.....	69	19	4	30.25	Marquette.
2	3.1	.06	.67	Fort Sully.....	East.	4	.01	+23	Fort Sully.....	78	6	3	.26	Escanaba.
3	14.2	.02	.71	Fort Sully.....	SE.	18	.00	+23	Fort Sully.....	15	19	4	.30	Saugeen.
4	14.3	.02	.66	Fort Sully.....	East.	18	.00	+16	Fort Sully.....	50	30	4	.29	Toronto.
5	15.1	.06	.84	Duluth.....	SE.	23	.00	+ 8	Duluth.....	76	8	4	.35	Kingston.
6	20.3	.04	.63	Leavenworth..	SE.	10	.00	+14	Leavenworth..	46	16	2	.23	Augusta.
7	21.3	.07	.77	Chicago.....	*	0	.04	+14	Toledo.....	67	8	0	.22	Augusta.
8	Oct. 1.3	.07	.73	Fort Sully.....	East.	27	.00	+22	Fort Sully.....	40	6	3	.27	Nashville.
9	11.2	.04	.82	Fort Sully.....	?	?	.00	+21	Fort Benton...	8	7	2	.30	Cincinnati.
10	11.3	.00	.82	Duluth.....	East.	20	.00	+11	Fort Sully.....	22	6	4	.30	Cincinnati.
11	12.1	.00	.71	Marquette.....	East.	25	.00	+ 5	Grand Haven..	48	18	4	.30	Lynchburg.
12	14.3	.08	.48	Fort Sully.....	East.	26	.00	+17	Fort Sully.....	19	6	0	.24	Vicksburg.
13	15.1	.05	.49	Escanaba	East.	35	.05	+13	Fort Sully.....	46	21	0	.24	Nashville.
14	16.3	.08	.83	Fort Sully.....	NE.	44	.00	+14	Fort Sully.....	53	3	0	.34	Philadelphia.
15	19.3	.03	.86	Omaha.....	East.	6	.00	+16	Omaha.....	37	10	0	.27	Cincinnati.
16	20.1	.00	.80	Omaha.....	East.	5	.00	+14	Omaha.....	54	9	0	.32	Cincinnati.
17	20.2	.00	.57	St. Paul.....	*	0	.00	+27	La Crosse	23	0	2	.25	Norfolk.
18	20.3	.01	.58	Marquette.....	ENE.	28	.00	+21	La Crosse	33	0	0	.27	Norfolk.
19	21.1	.07	.62	Marquette.....	East.	27	.00	+17	Alpena.....	59	8	2	.32	Norfolk.
20	31.2	.00	.76	Fort Sully.....	*	0	.00	+ 1	Alpena.....	79	3	4	.24	Nashville.
21	Nov. 17.3	.06	30.11	Alpena.....	SE.	15	.00	+ 5	Fort Benton...	40	10	4	.66	Philadelphia.
22	21.1	.07	29.69	St. Paul.....	SE.	31	.05	+ 6	Fort Benton...	67	5	3	.44	Lynchburgh.
23	21.2	.05	.73	Alpena.....	SE.	30	.05	+13	Fort Benton...	36	6	4	.30	Lynchburgh.
24	21.3	.09	.76	Escanaba	NE.	30	.06	+14	Fort Benton...	49	14	2	.24	Lynchburgh.
25	27.3	.02	.91	Quebec.....	East.	?	.00	— 4	Boston.....	80	7	0	.64	Breckenridge.
26	28.1	.00	30.09	Escanaba	?	?	.00	+ 6	Cheyenne	..	16	0	.71	Breckenridge.
27	Dec. 4.2	.07	.03	St. Paul.....	SE.	33	.00	+14	Fort Benton...	31	11	2	.38	Cincinnati.
28	6.3	.04	.00	Fort Sully.....	*	0	.00	+21	Fort Benton...	39	7	4	.41	Davenport.
29	7.1	.09	29.67	Pembina	East.	26	.05	+15	Fort Benton...	52	0	1	.39	Memphis.
	1873.													
30	Jan. 11.3	.01	.55	Fort Sully.....	*	0	.01	+20	Fort Sully.....	78	4	3	.57	Augusta.
31	12.3	.08	.73	Milwaukee	East.	25	.08	+22	Keokuk.....	85	16	4	.56	Boston.
32	Feb. 1.3	.05	.87	Halifax.....	SE.	16	.01	—13	Halifax.....	86	6	0	.74	Davenport.
33	10.1	.00	.50	Fort Garry	East.	38	.00	+19	La Crosse	61	13	4	.50	Wilmington.
34	10.2	.08	.43	Escanaba	East.	27	.06	+11	Grand Haven..	59	20	4	.41	Savannah.
35	Mar. 5.2	.02	.53	Fort Garry	East.	19	.00	+16	Leavenworth..	29	18	3	.69	Port Stanley.
36	5.3	.00	.65	Pembina	SE.	10	.00	+14	Omaha.....	79	12	0	.72	Baltimore.
37	6.1	.01	.46	Fort Garry	?	?	.00	+15	Omaha.....	79	12	0	.78	Lynchburgh.
38	13.1	.02	.94	Escanaba	SE.	40	.00	+13	Marquette.....	79	8	4	.42	Nashville.
39	13.2	.02	.95	Fort Garry	?	?	.00	+20	Denver.....	10	0	1	.33	Augusta.
40	13.3	.00	.81	Fort Garry	*	0	.00	+15	Omaha.....	52	8	0	.40	Augusta.
41	16.3	.01	.75	Breckenridge..	ENE.	22	.00	+14	Omaha.....	44	16	2	.40	Cincinnati.
42	22.3	.01	.66	Marquette.....	?	?	.00	+15	Leavenworth..	45	10	2	.23	Jacksonville.
43	27.3	.00	.41	Omaha.....	SE.	42	.00	+16	Omaha.....	52	32	1	.37	Cape May.
44	April 4.1	.08	.31	Yankton	*	0	.03	+21	Leavenworth..	79	18	3	.26	Kingston.
45	4.3	.05	.50	Leavenworth..	*	0	.01	+24	Keokuk.....	59	8	4	.36	Kingston.
46	21.2	.05	.45	Leavenworth..	SE.	29	.00	+20	Leavenworth..	17	15	3	.00	Indianola.
47	May 16.1	.02	.74	Eastport	?	?	.02	— 2	Portland, Me ..	59	4	4	.16	Duluth.
48	July 6.3	.04	.78	Omaha.....	*	0	.04	+ 7	Leavenworth..	67	2	3	.09	Port Stanley.
49	Sept. 11.3	.09	.62	Marquette.....	ENE.	24	.02	+24	Marquette	60	16	1	.12	Philadelphia.
50	Oct. 2.2	.06	.92	Omaha.....	East.	?	.00	+15	Yankton	64	8	2	.27	Marquette.
51	2.3	.06	.95	Yankton	*	0	.00	+18	Yankton	84	0	4	.32	Marquette.
52	9.2	.00	.49	Fort Garry	NE.	18	.00	+24	Omaha.....	22	9	0	.34	Chatham.
53	9.3	.02	.58	Fort Garry	East.	36	.02	+21	Keokuk.....	69	12	0	.36	Chatham.
54	10.2	.04	.68	Fort Garry	?	?	.00	+14	Davenport	46	0	0	.23	Chatham.
55	10.3	.02	.86	Duluth.....	East.	16	.00	+20	Duluth.....	75	5	0	.18	Chatham.
56	14.3	.02	.72	Fort Sully.....	*	0	.02	+19	Omaha.....	52	17	0	.44	Saugeen.
57	15.3	.03	.95	St. Paul.....	East.	21	.00	+14	Keokuk.....	55	12	4	.52	Cape May.
58	Nov. 10.1	.02	.48	Father Point..	East.	30	.00	— 2	Father Point..	69	19	4	.28	Vicksburg.
59	10.2	.09	.87	Fort Sully	?	?	.00	+22	Leavenworth..	34	2	0	.19	Indianola.
60	Dec. 15.2	.00	.70	Fort Garry	East.	?	.00	+20	Marquette	46	20	0	.38	Wilmington.
61	15.3	.00	.80	Fort Garry	?	?	.00	+15	Marquette	62	8	0	.40	Norfolk.
62	16.2	.00	.71	Fort Sully	?	?	.00	+16	Leavenworth..	47	0	4	.29	New London.
63	16.3	.07	.77	Fort Garry	?	?	.00	+15	Davenport	66	8	4	.30	Montreal.
64	17.2	.04	.87	Detroit	East.	42	.00	+17	Toledo.....	58	4	4	.26	Montgomery.
65	17.3	.04	.94	Cleveland.....	East.	28	.00	+14	Erie	89	8	4	.20	Lake City.
66	18.1	.05	.93	Eastport.....	East.	40	.00	0	Halifax.....	97	0	0	.29	Pembina.
67	30.2	.09	.72	Fort Garry	East.	?	.00	+11	Marquette	55	8	0	.63	Knoxville.
68	31.3	.00	.39	Pembina	*	0	.00	+15	Duluth	78	8	0	.56	Norfolk.

TABLE CXX.—*Total rainfall at all stations east of the Rocky Mountains, etc.*—Continued.

No.	Date.	Total rain.	Low bar.	Station.	Low moved.		Rain in low.	Thermometer.		Humidity.	Wind vel.	Cloud.	High bar.	Station.
					Direction	Vel.		Above normal	Station.					
	1874.							°						
69	Jan. 1.1	.07	.47	Fort Garry	*	0	.00	+23	Omaha.....	80	0	1	.52	Augusta.
70	17.2	.06	.25	Fort Garry	?	?	.00	+18	Marquette	70	28	4	.56	Philadelphia.
71	17.3	.08	.53	Breckenridge..	?	?	.01	+14	Keokuk.....	46	18	4	.60	Philadelphia.
72	25.3	.03	.83	Fort Benton...	?	?	.00	+11	Keokuk.....	61	16	4	.75	Brockville.
73	Feb. 9.3	.09	.93	Fort Garry	?	?	.00	+13	Cheyenne	41	12	4	.47	Vicksburg.
74	10.2	.07	.83	Omaha.....	?	?	.00	+15	Cheyenne	0	12	1	.32	Vicksburg.
75	18.3	.09	.45	Fort Sully	East.	23	.00	+12	Denver	42	0	0	.45	Brockville.
76	26.3	.09	.95	Fort Sully	?	?	.00	+ 5	Dubuque.....	84	4	1	.36	Vicksburg.
77	Mar. 2.2	.02	.52	Marquette	East.	20	.00	+22	Marquette	48	12	4	.25	Sydney.
78	2.3	.00	.53	Leavenworth..	?	?	.00	+15	Keokuk.....	66	12	2	.36	Sydney.
79	24.3	.00	.66	Fort Sully	East.	25	.00	+24	Fort Sully	31	0	2	.47	Norfolk.
80	25.1	.06	.69	Marquette	East.	38	.01	+16	Alpena.....	36	12	3	.50	Norfolk.
81	May 6.1	.02	.56	Sydney	?	?	.01	— 2	Halifax.....	51	4	1	.16	Indianola.
82	6.3	.01	.79	Fort Sully.....	?	?	.00	+10	Cheyenne	33	8	0	.17	Vicksburg.
83	7.1	.06	.74	Fort Sully.....	East.	?	.00	+10	Cheyenne	53	0	0	.23	Vicksburg.
84	7.2	.00	.44	Fort Sully.....	East.	?	.00	+22	Fort Sully	17	15	3	.20	Vicksburg.
85	7.3	.00	.46	Fort Sully.....	East.	?	.00	+13	Yankton	40	15	0	.25	Vicksburg.
86	8.3	.04	.12	Fort Sully.....	NE.	14	.00	+25	Pembina.....	37	12	4	.32	New Orleans.
87	July 6.3	.00	.69	Breckenridge..	?	?	.00	+14	Chicago.....	54	4	0	.19	Philadelphia.
88	18.1	.00	.54	Pembina	East.	20	.00	+ 8	Yankton	72	1	2	.20	Philadelphia.
89	19.1	.09	.65	Marquette	East.	29	.07	+15	Yankton	59	8	4	.29	Philadelphia.
90	Aug. 11.3	.06	.69	Alpena.....	East.	26	.06	+19	Alpena.....	78	7	1	.11	Vicksburg.
91	16.1	.07	.78	Breckenridge..	SE.	13	.07	+12	Yankton	89	9	2	.26	Saugeen.
92	Oct. 3.3	.01	.83	Bismarck	North.	28	.00	+17	Bismarck	53	13	2	.37	Marquette.
93	15.2	.02	.65	Bismarck	?	?	.01	+15	Cheyenne	9	16	0	.40	Norfolk.
94	19.3	.01	.74	Duluth.....	East.	?	.01	+20	Duluth	57	4	1	.22	Augusta.
95	20.1	.07	.92	St. Paul.....	East.	?	.01	+14	Alpena.....	45	12	4	.34	Norfolk.
96	Nov. 1.1	.08	.54	Marquette	East.	25	.01	+28	Duluth	66	10	0	.52	Vicksburg.
97	2.2	.01	.65	Duluth.....	East.	15	.00	+20	Chicago.....	33	16	0	.34	Norfolk.
98	3.2	.00	.47	Bismarck	?	?	.00	+20	Chicago.....	35	17	0	.43	Sydney.
99	3.3	.00	.52	Bismarck	?	?	.00	+18	Grand Haven..	62	16	0	.42	Sydney.
100	4.1	.01	.47	Bismarck	?	?	.00	+29	Leavenworth..	73	22	4	.42	Lynchburgh.
101	13.2	.05	.53	Fort Sully.....	East.	...	.01	+14	Fort Sully	46	12	2	.64	Saugeen.
102	13.3	.01	.61	Bismarck	East.	?	.01	+11	Bismarck	79	4	4	.65	Parry Sound.
	1875.													
103	Jan. 15.3	.08	.37	Cape Rozier ...	?	?	.00	— 1	Chatham.....	86	5	0	.45	Ottawa.
	1877.													
104	Jan. 28.1	.00	.87	Marquette	SE.	27	.00	+19	Marquette	61	4	0	.43	Albany.
105	Feb. 8.2	.05	.86	Bismarck	?	?	.00	+18	Duluth.....	33	3	2	.31	Yankton.
106	8.3	.02	.72	Bismarck	?	?	.00	+18	Pembina	78	18	0	.24	Milwaukee.
107	9.2	.00	.51	Bismarck.....	?	?	.00	+23	Duluth.....	39	8	1	.21	Port Stanley.
108	10.1	.05	.74	Bismarck.....	SE.	17	.00	+20	Marquette	70	4	0	.24	Washington.
109	10.3	.00	.78	St. Paul	East.	27	.00	+23	St. Paul.....	74	6	0	.27	Knoxville.
110	20.3	.02	.60	Bismarck.....	?	?	.00	+26	Duluth.....	67	12	0	.44	Shreveport.
111	21.1	.00	.51	Bismarck.....	East.	12	.00	+33	Fort Sully.....	67	16	4	.41	Shreveport.
112	26.3	.00	.78	Sydney	?	?	.00	— 3	Chatham.....	90	3	0	.68	Fort Garry.
113	27.1	.00	.91	Sydney	?	?	.00	— 8	Chatham.....	79	5	0	.66	Fort Garry.
114	27.3	.00	.81	Sydney	?	?	.00	— 6	Sydney	57	7	0	.42	Fort Garry.
115	28.1	.00	.82	Sydney	?	?	.00	— 2	Halifax	78	4	0	.40	Davenport.
116	Apr. 11.2	.05	.66	Halifax	NE.	?	.02	— 3	Sydney	71	12	4	.27	Marquette.
117	22.2	.03	.73	Yankton	NE.	22	.00	+30	Marquette	30	16	0	.38	Cleveland.
118	May 23.2	.08	.63	Halifax	?	?	.07	— 4	Halifax	80	3	4	.27	Fort Garry.
119	Aug. 4.1	.09	.53	Bismarck.....	?	?	.00	+14	Bismarck.....	71	7	1	.16	Milwaukee.
120	4.3	.02	.50	Bismarck.....	?	?	.02	+12	Bismarck.....	65	15	4	.10	Milwaukee.
121	Sept. 30.1	.00	.59	Duluth.....	East.	17	.00	+12	La Crosse	79	9	0	.23	Boston.
122	Oct. 23.2	.09	.44	Bismarck.....	East.	?	.00	+10	Yankton	38	13	3	.22	Cape Lookout.
123	23.3	.02	.61	Bismarck.....	East.	12	.00	+ 7	Yankton	61	12	2	.25	Knoxville.
124	Nov. 4.1	.02	.87	Leavenworth..	East.	27	.00	+16	Leavenworth..	64	8	4	.43	Washington.
125	6.3	.00	.50	Bismarck.....	NE.	26	.00	+15	Fort Garry....	72	28	0	.49	Washington.
126	11.2	.01	.60	Bismarck.....	?	?	.00	+25	Bismarck.....	45	8	2	.42	Vicksburg.
127	11.3	.07	.64	Bismarck.....	?	?	.00	+14	Bismarck.....	71	11	2	.43	Nashville.
128	12.3	.00	.56	Bismarck.....	?	?	.00	+12	Bismarck.....	79	3	4	.32	Knoxville.
129	Dec. 14.3	.02	.59	Bismarck.....	?	?	.00	+23	Bismarck.....	62	1	4	.51	Smithville.
130	15.1	.09	.59	Fort Garry....	?	?	.00	+26	Bismarck.....	53	6	1	.51	Cape Lookout.

The average number of the cases shown in Table CXX for the different months of the year, was as follows:

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
2.0	6.0	4.3	1.7	2.7	0	1.3	1.3	2.2	6.7	5.0	3.5

October is the month of greatest frequency, and June the month of least frequency. During the six coldest months of the year the cases are three times as frequent as during the six warmest months. Very few cases occur in summer. The mean height of the barometer at the low centers was 29.68 inches; and the pressure was somewhat less for the cases in which the low center was in the western part of the United States than when the low center was near the Atlantic coast. For the 13 cases in which the low center was near the Atlantic coast the average temperature shown at some neighboring station was 3°.8 below the normal; for the remaining 117 cases, the average temperature at some station near the low center was 16.6 *above* the normal. For the 13 cases in which the low center was near the Atlantic coast the average pressure at the center of the high area on the west side was 30.42 inches; for the remaining 117 cases the average pressure at the center of the high area on the east side was 30.36 inches.

258. Table CXX apparently shows that considerable depressions of the barometer sometimes occur without rain, or at most with very little rain. It may be said that these cases of low pressure generally occurred in that region where the stations of observation are widely separated, and that rain may have fallen at intermediate points where there was no observer. The long continuance of the rainless condition in some of the cases is pretty conclusive evidence that in these cases the fall of rain must have been very slight over the entire area of low pressure. For 40 hours, from October 19.3 to 21.1, 1872, the total rainfall at all the stations east of the Rocky Mountains was only 0.11 inch. Moreover, for 24 hours preceding October 19.3, the rainfall east of the Rocky Mountains was quite small, and the whole of it was connected with an area of low pressure which prevailed near the Atlantic coast, and can scarcely be supposed to have had any sensible influence upon the movements of the atmosphere in the extreme northwestern part of the United States.

The entire amount of rain which fell at the northwestern stations during the month of October, 1872, was small. During the last four days of the month there was considerable rainfall at a few of the stations, and I have therefore limited my comparison to the first 27 days of the month. Table CXXI shows the total rainfall for the first 27 days of October, at all the stations west of the meridian of 86° from Greenwich, and north of the parallel of 38° latitude, including also all the stations west of the Rocky Mountains.

TABLE CXXI.—*Total rainfall for the first twenty-seven days of October*, 1872.

Station.	Rain.	Station.	Rain.	Station.	Rain.	Station.	Rain.
Breckenridge	0.40	Duluth	0.10	Keokuk	0.42	San Diego	0.00
Cheyenne	.08	Escanaba	.25	Leavenworth	.62	San Francisco	.11
Chicago	.44	Fort Benton	.09	Marquette	.45	Santa Fé	.25
Corinne	.61	Fort Sully	.02	Milwaukee	.56	St. Louis	.54
Davenport	.51	Grand Haven	.31	Omaha	.09	St. Paul	.00
Denver	.40	Indianapolis	.55	Portland, Oregon	.93	Virginia City	.12

We see from this table that the month of October was a period of general drought throughout the northwestern part of the United States, and this confirms the conclusion that from October 19.3 to 21.1 there could not have been much rain at any place in this region.

259. In order to exhibit the phenomena of this period more clearly I have prepared Plate LI, which shows one isobar for each of the days October 19, 20 and 21. The most western oval represents the isobar 29.8 for October 19. The next curve represents the isobar 29.6 for October

20, and the most eastern curve represents the isobar 29.8 for October 21. Each of the curves corresponds to the 4.35 p. m. observation. It will be seen that during the first 24 hours the center of least pressure moved less than 5 miles per hour; but during the next 24 hours the average motion was nearly 20 miles per hour. During these 48 hours not a drop of rain was recorded at any station within the area of a pressure less than 30 inches, although on the 20th of October this area had a diameter of 1,500 miles.

The plate shows also the direction and velocity of the winds October 20, 4:35 p. m.

One feather on an arrow indicates a velocity less than 5 miles per hour; two feathers a velocity from 5 to 10 miles per hour; three feathers a velocity from 10 to 15 miles, etc. We perceive that this area of low pressure had great geographical extent; and there was an area of high pressure (isobar 30.2 inches) on its western side, and also an area of high pressure (isobar 30.2 inches) on its eastern side. On the eastern side of this low area, within the isobar 29.9 inches, the average gradient was one-tenth of an inch to 98.3 miles, and on the western side it was one-tenth of an inch to 95.2 miles. Average gradient for both sides was one-tenth of an inch to 96.7 miles. The average velocity of the wind within the isobar 29.9 inches was 13.2 miles per hour. Throughout the entire extent of this low area during the preceding 8 hours, the barometric pressure diminished; the average decrease being 0.17 inch, and the decrease on the western side of the low center was nearly as great as on the eastern side. Everywhere throughout this low area the temperature was above the normal for the given time and place, the average for the entire area being 12.3° F.; and the greatest departures from the normal were in the neighborhood of the low center, on its eastern side.

260. In order to determine how far the facts here developed may be peculiar to this particular case I have selected another example from Table CXX, viz, that of 1874, May 6–8. For 32 hours, from May 6.3 to May 7.3, the total rainfall at all the stations east of the Rocky Mountains was only 0.07 inch; and from May 6.1 to May 8.3, a period of 72 hours, the rainfall within the area of low pressure, was almost equally small. Table CXXII shows the total rainfall for this period at all the Signal Service stations from the Atlantic Ocean to the Pacific Ocean, and it also shows each station at which rain was observed.

TABLE CXXII.—*Total rainfall at all the Signal Service stations, May,* 1874.

Date.	Total rain.	Place of rainfall.
May 6.1	0.07	San Francisco, .05; Knoxville, .01; Father Point, .01.
6.2	.38	San Francisco, .15; Portland, Oregon, .03; Cape Rozier, .20.
6.3	.01	Norfolk, .01.
7.1	.06	New London, .06.
7.2	.00	
7.3	.00	
8.1	1.02	Detroit, .01; Pittsburgh, .01; Burlington, .01; Montreal, .03; Mount Washington, .16; Punta Rassa, .03; Key West, .77.
8.2	.57	San Diego, .06; Salt Lake City, .26; Burlington, .03; Mt. Washington, .22.
8.3	.06	Portland, Oregon, .02; Mt. Washington, .04.

The rain at San Francisco, May 6.2, may have contributed somewhat to the formation of the low area which was then developing beyond the ridge of the Rocky Mountains, but the rain at Cape Rozier belonged to a low area which was passing off over the Atlantic Ocean. May 8.1 Key West was far beyond the limits of the low area, and the rain at that place can not be supposed to have had any direct influence upon the low area. Neither can the rain on Mount Washington be supposed to have had any appreciable influence upon a low area whose center was so remote. May 8.2 the rainfall at Mount Washington was too remote to have had any appreciable influence on the low area, but the rain at Salt Lake City may have had an appreciable influence on the movement of the winds within the low area. Thus we see that during a perion of 72 hours there were only two cases of rainfall (amount 0.15 inch and 0.26 inch) which can be supposed to have had any appreciable influence upon the low area which prevailed, or was in the process of formation, in the northwestern part of the United States.

Plate LI, Fig. 2, exhibits one isobar for each of the days, May 6, 7, and 8 corresponding to the 11 p. m. observation. The plate shows also the direction and velocity of the winds May 7, 11 p. m. At the center of this low area the barometer fell below 29.2 inches May 8 at 11 p. m. and a pressure less than 30 inches extended from the Atlantic Ocean to the borders of the Pacific, having on its southeast side an area of high pressure (isobar 30.3 inches) with indications of a high area over the Pacific Ocean on its western side, the barometer at Portland, Oregon, standing at 30.19 inches May 9 at 7:35 a. m. On the eastern side of this low area the average gradient was one-tenth of an inch to 78.8 miles, and on the western side it was one-tenth of an inch to 127.1 miles. Average gradient for both sides was one-tenth of an inch for 102.9 miles. The average velocity of the wind was 8.5 miles per hour. Throughout this low area during the preceding 8 hours, the changes of barometric pressure were small, the average change for all the stations without regard to algebraic signs being 0.05 inch. On the western side of the low area the average change was +0.06 inch, and on the eastern side it was — 0.01 inch. In the neighborhood of the low center on its eastern side there was a region of small extent where the diminution of pressure during the preceding 8 hours amounted to 0.15 inch. Throughout the northeastern portion of the United States the temperature was a little below the normal; but with this exception the temperature within the low area, east of the Rocky Mountains, was everywhere above the normal to an average amount of 12°.4 F., and the greatest elevation above the normal was in the neighborhood of the low center on its eastern side.

261. On comparing the results for these two cases we find a very marked degree of accordance. In each case we find a low area of great geographical extent situated between two areas of high pressure. For the first case there was an average gradient of one-tenth of an inch to 96.7 miles and for the second case a gradient of one-tenth of an inch for 102.9 miles. The average for the two cases is one-tenth of an inch for 99.8 miles, which equals 1.75^{mm} to 1° of latitude. This is but little more than half the average gradient for the great storms of the United States which are accompanied by considerable rainfall (see Chapter II, article 187). The average velocity of the wind for the two cases was 10.8 miles per hour, or 4.85 meters per second; which is less than half the average velocity for great storms which are accompanied by considerable rainfall. The most prominent characteristics of these two cases of low barometer without rain are feeble gradients with moderate winds and a considerable elevation of temperature above the normal (average 12° F.), throughout nearly the whole extent of the low area.

262. Table CXX furnishes other examples similar to the preceding, though not quite so remarkable for their great geographical extent and for the amount of the barometric depression. From November 2.1 to November 4.1, 1874, a period of 56 hours, the amount of rain which fell within the low area, or within the region where the low area was forming, was extremely small. Table CXXIII shows the total rainfall for this period at all the Signal Service stations from the Atlantic to the Pacific, and it also shows each station where rain was observed.

TABLE CXXIII.—*Total rainfall at all the Signal Service stations, November*, 1874.

Date.	Total rain.	Place of rainfall.
Nov. 2.1	0.20	Grand Haven, .05; Oswego, .10; Montreal, .01; Quebec, .01; Mount Washington, .02; Halifax, .01.
2.2	.01	Sydney, .01.
2.3	.16	Charleston, .07; Jacksonville, .09.
3.1	.57	Portland, Oregon, .20; San Diego, .07; Charleston, .10; Jacksonville, .20.
3.2	.19	Portland, Oregon, .19.
3.3	.10	Portland, Oregon, .08; Pike's Peak, .02.
4.1	.01	Punta Rassa, .01.

November 2.1 all the rain fell beyond the limits of the low area on its eastern side. November 2.3 all the rain fell beyond the limits of the low area on its southeast side. November 3.1, half the rain fell beyond the limits of the low area on its southeast side; the remainder fell on the Pacific coast where it may have had some influence in extending the low area. November 3.2

slight rain on the Pacific coast; November 3.3 very slight rain on the Pacific coast. Throughout these 56 hours there was no rain reported within the low area except on the Pacific coast, where it amounted in the aggregate to 0.54 inch. During all this time the low center remained nearly stationary, with a small movement westward, owing to an extension of the low area on that side.

From February 8.2 to February 10.3, 1877, a period of 64 hours, throughout the northwestern part of the United States there prevailed an area of low pressure within which the observations showed no rainfall except a little near the Pacific coast. Table CXXIV shows the total rainfall for this period at all the Signal Service stations from the Atlantic to the Pacific, and it also shows each station where rain was observed.

TABLE CXXIV.—*Total rainfall at all the Signal Service stations, February*, 1877.

Date.	Total rain.	Place of rainfall.
Feb. 8.2	0.05	Dodge City, .01; Leavenworth, .01; Keokuk, .02; Chatham, .01.
8.3	.20	Portland, Oregon, .18; Punta Rassa, .01; Halifax, .01.
9.1	.29	Portland, Oregon, .19; Quebec, .10.
9.2	.03	Portland, Oregon, .03.
9.3	.25	Portland, Oregon, .03; Knoxville, .12; St. Marks, .10.
10.1	.06	Virginia City, .01; Quebec, .05.
10.2	.35	Virginia City, .17; Knoxville, .04; Jacksonville, .14.
10 3	.00	

The total rain which fell during these 64 hours beyond the low area on its eastern or southeastern side was 0.62 inch. The total rainfall at Portland, Oregon, was 0.43 inch, and at Virginia City 0.18 inch. During all this time an area of low pressure prevailed throughout the northwestern part of the United States, which advanced eastward at a very slow rate.

263. These examples are sufficient to show that in the northwestern part of the United States there are sometimes formed areas of low pressure having great geographical extent, and accompanied by an amount of rain which is extremely small. Can we suppose that this trivial amount of rain was the cause of these low areas? If we examine Table CXIII, and notice the cases in which an extraordinary fall of rain was accompanied by only a moderate depression of the barometer, I think we must conclude that in the cases above quoted from Table CXX the depression of the barometer can not have been due in any appreciable extent to the amount of rain which fell. What then was the cause which led to the formation of these low areas, and which maintained them for so long a period?

We have have found that throughout nearly the whole extent of these low areas, the average temperature was 12° above the normal; and in the neighborhood of the low center it was 20° above the normal. We can not ascribe this unusual temperature to the heat developed in the condensation of aqueous vapor. It seems necessary to ascribe it to the direct effect of the sun's rays acting upon the sandy soil of the northwestern plains and of the Salt Lake Basin. This, then, seems to be the primary cause of these areas of low pressure. It will also be seen from column 14 of Table CXX, that these low areas in the Northwest are always attended by an area of high pressure on the east or southeast side, where the average height of the barometer is found to be 30.36 inches. This high temperature over the northwestern plains, combined with an area of high pressure on the east or southeast side, is sufficient to cause a general movement of the surrounding air towards the heated region. The Signal Service maps are too limited in extent to show satisfactorily what were the atmospheric conditions on the north and west sides of the low area; but we must conclude that the colder air from the North would press down to displace the warmer air of the low area. The international weather maps show that such is uniformly the case under like circumstances. Several of the plates of Chapter II (Plates XX, XXII, XXVII, XXIX, XXX, XXXI), show that every low area has an adjoining area of high pressure on at least two sides, with, perhaps, the exception of the case in which there are two centers of low pressure so near each other as to interfere. We must conclude that the air presses in towards this heated region, not only from its southeast side but also from the northwest side. Thus we find all the forces requisite to generate a cyclonic movement of the winds about the center of the heated region. In order to repair the

force which is lost by friction, and maintain this cyclonic motion for several days, the forces here described must be continually recruited. The areas of high pressure are recruited from the air which ascends from areas of low pressure. The heat of the central area is continually recruited by the direct action of the sun's rays, and thus the cyclonic movement of the low area may be maintained for a long time, while the steady pressure of the air on the western side (arising from the same causes which determine the average system of circulation of the winds) fills up the low area on its western side, and thus crowds the low area slowly eastward.

264. If areas of low pressure of great geographical extent may be formed and maintained for several days with very little rain, is there no difference between the low areas which are attended by a heavy rainfall and those which are attended by very little rain? Differences do exist, and generally they are strongly marked. The following are some of them:

Characteristics of areas of low pressure.

With excessive rainfall.	With little or no rain.
1. Steep barometric gradients.	1. Feeble barometric gradients.
2. Violent winds.	2. Moderate winds.
3. Rapid changes of barometric pressure.	3. Slow changes of barometric pressure.
4. Rapid progressive movement.	4. Slow progressive movement.

These are the characteristics of an area of low pressure which stands alone, uninfluenced by the proximity of a second area of low pressure. When two areas of low pressure are formed near each other, their movements are often very complicated. The preceding investigation must lead us to conclude that in the great areas of low pressure which are accompanied by an excessive rainfall, the areas of high pressure which attend them must exert a very important influence upon the movements of the air within the low areas.

Cases of heavy rains in Europe.

265. In order to study the influence of rainfall upon barometric pressure under different geographical influences, I have prepared Table CXXV, showing for three years the principal rainfalls in Europe. I selected from the Bulletin of International Meteorological Observations all those cases in which a rainfall of 2½ inches in 24 hours was reported at any station during the years 1878, 1879, and 1880. Column 1 gives the number of reference; column 2, the date of observation; column 3, the station of heavy rainfall; column 4, the latitude of the station; column 5, its longitude from Greenwich; column 6, its elevation (in English feet) above sea level; column 7, the rainfall in 24 hours expressed in English inches; column 8, the height of the barometer reduced to sea level; column 10, the direction of the wind at the given station at the date of observation; column 9, its direction 24 hours previous, and column 11, its direction 24 hours succeeding the given date; column 12 shows the height of the barometer at the center of low pressure with which the rainfall is believed to have been associated; column 13 shows the direction of the rain center from the center of low pressure, and column 14 shows the distance expressed in English miles.

TABLE CXXV—*Rainfall amounting to 2½ inches in 24 hours in Europe, according to the International Bulletin.*

No.	Date.	Station.	Lat.	Long. from Greenwich.	Elevation.	Rain.	Bar. red'd.	Direction of the wind.			Low bar.	Rain from low.	
								Prev. obs.	At date.	Sub. obs.		Direction.	Dist.
	1878.		° ′	° ′	*Feet.*	*Inch.*						°	
1	Jan. 27	Valona, Turkey...	40 27	19 27 E.	105	2.950	29.29	S.	SE.	NE.	29.29	*	0
2	Mar. 25	Pic du Midi, France	42 15	0 8W.	7,763	2.839	.94	NW.	NW.	N.	.48	S. 75W.	384
3	29	Udine, Italy.....	46 4	13 13 E.	381	2.704	.59	SW.	SE.	S.	28.85	East.	475
4	29	Genoa, Italy.....	44 24	8 55 E.	157	3.385	.45	NE.	NE.	SW.	.85	S. 66 E.	300
5	30	Tours, France	47 24	0 41 E.	167	2.749	.33	ESE.	NNW.	W.	29.01	S. 58W.	200
6	Apr. 11	Greenwich, England	51 29	0 0	159	2.820	30.04	E.	E.	E.	.95	N. 57 E.	110
7	21	Moncalieri, Italy .	45 0	7 41 E.	846	2.520	29.64	NNW.	NNW.	NNW.	.56	N. 56W.	75
8	May 3	Urbino, Italy.....	43 43	12 37 E.	1,480	2.665	.82	NNE.	NNE.	NE.	.65	N. 31W.	356
9	June 3	Zurich, Switzerland	47 22	8 40 E.	1,542	5.409	30.07	SW.	SE.	SE.	.85	S. 26 E.	185
10	5	Trieste, Austria ..	45 39	13 46 E.	85	2.705	29.90	NW.	Calm.	NE.	.52	S. 23W.	770
11	15	Trieste, Austria ..	45 39	13 46 E.	85	2.607	.56	NW.	E.	SE.	.49	S. 15W.	215
12	July 2	Lorient, France ..	47 45	3 21W.	86	2.842	.87	SSE.	WSW.	NW.	.76	S. 79W.	225
13	25	Helder, Netherlands.....	52 58	4 45 E.	0	2.571	.69	ENE.	NE.	SSW.	.64	S. 57 E.	410
14	26	Trieste, Austria ..	45 39	13 46 E.	85	3.500	.65	NW.	ESE.	E.	.63	N. 72W.	50
15	26	Weissenburg, Germany	49 2	10 58 E.	1,414	2.913	.78	WNW.	NW.	W.	.63	N. 36W.	310
16	Aug. 4	Udine, Italy.....	46 4	13 13 E.	381	2.756	.81	N.	S.	SW.	.75	S. 49 E.	410
17	6	Nottingham, England	52 57	1 10W.	174	2.516	.68	SE.	S.	SW.	.62	S. 84 E.	345
18	20	Hernosand, Sweden	62 32	17 57 E.	46	4.666	.62	NW.	N.	N.	.39	North.	225
19	25	Udine, Italy.....	46 4	13 13 E.	381	2.732	.66	N.	NW.	SE.	.47	S. 42 E.	670
20	Sept. 10	Leghorn, Italy....	43 33	10 18 E.	79	2.780	.87	W.	N.	ENE.	.86	*	0
21	15	Trieste, Austria...	45 39	13 46 E.	85	2.522	.86	Calm.	Calm.	W.	.85	N. 29 E.	185
22	15	Vicenza, Italy	45 33	11 34 E.	184	2.591	.92	S.	NE.	ESE.	.85	North.	130
23	20	Trieste, Austria ..	45 39	13 46 E.	85	6.408	.93	WSW.	W.	ENE.	.84	N. 73 E.	315
24	22	Pola, Austria	44 52	13 51 E.	105	3.544	.80	SSE.	ENE.	WSW.	.77	N. 32W.	200
25	24	Trieste, Austria...	45 39	13 46 E.	85	2.902	.69	W.	SSE.	ENE.	.58	N. 60 E.	280
26	25	Udine, Italy.....	46 4	13 13 E.	381	4.086	.58	E.	N.	Calm.	.47	N. 61 E.	336
27	Oct. 1	Lyons, France....	45 41	2 30 E.	981	4.250	30.14	.....	.....	.....	30.06	*	0
28	7	Nismes, France...	43 50	4 21 E.	188	5.149	29.99	S.	S.	SE.	29.06	S. 43 E.	880
29	8	Macon, France....	46 18	4 50 E.	604	2.990	.83	WSW.	WSW.	W.	28.96	S. 43 E.	740
30	8	Puy de Dome, France	45 46	2 58 E.	4,813	5.830	.83	SW.	W.	W.	.96	S. 33 E.	750
31	9	Bergamo, Italy...	45 42	9 43 E.	1,252	3.228	.90	NE.	SW.	S.	.85	S. 65 E.	990
32	13	Rome, Italy	41 54	12 29 E.	164	3.504	.86	SW.	S.	S.	29.85	S. 45 E.	160
33	22	Privas, France ...	44 45	4 36 E.	997	4.214	.70	S.	NW.	NW.	.68	*	0
34	26	Nice, France.....	43 42	7 16 E.	29	3.052	.78	W.	SW.	NW.	.01	S. 33 E.	660
35	Nov. 2	Carcassonne, France	43 13	2 21 E.	384	2.560	30.13	NE.	W.	W.	.44	N. 82W.	420
36	12	Malta, Mediterranean	36 0	14 30 E.	70	3.500	29.88	SE.	SE.	S.	.88	*	0
37	14	Trieste, Austria...	45 39	13 46 E.	85	3.464	.23	Calm.	SW.	WSW.	.23	*	0
38	14	Udine, Italy.....	46 4	13 13 E.	381	3.020	.30	Calm.	N.	S.	.23	N. 42W.	40
39	14	Valona, Turkey...	40 27	19 27 E.	105	2.800	.78	SE.	S.	S.	.23	S. 40 E.	465
40	19	Moncalieri, Italy .	45 0	7 41 E.	846	2.952	30.08	N.	WNW.	WNW.	.83	N. 10W.	405
41	24	Lisbon, Portugal .	38 42	9 8W.	312	3.338	29.60	S.	SSW.	SSW.	.23	S. 7W.	288
42	Dec. 11	Greasque, France.	43 25	5 37 E.	1,056	2.571	.56	N.	W.	NW.	.42	N. 87W.	200
43	17	Trieste, Austria...	45 39	13 46 E.	85	3.154	.56	NE.	Calm.	Calm.	.31	S. 21 E.	290
44	17	Valona, Turkey ..	40 27	19 27 E.	105	4.140	.85	W.	S.	SW.	.31	S. 28 E.	950
45	23	Santiago, Spain ..	42 53	8 28W.	863	2.549	.89	SW.	S.	SE.	.46	N. 60 E.	1,100
	1879.												
46	Jan. 10	Valona, Turkey ..	40 27	19 27 E.	105	3.940	.76	S.	S.	SE.	.5	S. 29 E.	215
47	Feb. 1	Nottingham, England	52 57	1 10W.	174	2.770	30.08	ESE.	SE.	ENE.	.53	N. 79 E.	408
48	9	Santiago, Spain ..	42 53	8 28W.	863	3.048	29.51	S.	S.	SW.	28.51	S. 51 E.	890
49	10	Santiago, Spain ..	42 53	8 28W.	863	2.713	.38	S.	SW.	SW.	.43	S. 36 E.	584
50	15	Genoa, Italy	44 24	8 55 E.	157	2.587	.46	Calm.	N.	SE.	29.38	N. 49 E.	200
51	17	Mont Louis, France	42 30	2 7 E.	5,203	2.917	.71	SSW.	WSW.	W.	28.86	S. 18 E	920
52	Mar. 22	Genoa, Italy.....	44 24	8 55 E.	157	2.657	.58	Calm.	S.	NE.	29.45	N. 79 E.	220
53	23	Trieste, Austria...	45 39	13 46 E.	85	2.976	.53	E.	Calm.	E.	.39	N. 56 E.	470
54	27	Trieste, Austria...	45 39	13 46 E.	85	3.511	63	S.	E.	W.	.30	S. 78 E.	852
55	Apr. 21	Genoa, Italy.....	44 24	8 55 E.	157	3.346	.55	SW.	NE.	S.	.22	S. 65 E.	480
56	29	Rome, Italy	41 54	12 29 E.	164	2.598	.69	W.	N.	E.	.64	S. 45 E.	160
57	May 10	Puy de Dome, France.....	45 46	2 58 E.	4,813	3.906	.84	NW.	NNW.	N.	.38	S. 80W.	738

TABLE CXXV.—*Rainfall amounting to 2½ inches in 24 hours in Europe, etc.*—Continued.

No.	Date.	Station.	Lat.	Long. from Greenwich.	Elevation.	Rain.	Bar. red'd.	Direction of the wind.			Low bar.	Rain from low.	
								Prev. obs.	At date.	Sub. obs.		Direction.	Dist.
	1879.		° ′	° ′	*Feel.*	*Inch.*						°	
58	26	Mondovi, Italy ...	44 22	7 48 E.	1,824	3.378	.72	W.	WNW.	N.	.65	N. 18W.	257
59	June 18	Hamburg, Germany.....	53 33	9 58 E.	85	3.366	.62	SW.	S.	WSW.	.34	S. 24W.	180
60	July 14	Nismes, France...	43 51	4 21 E.	188	2.760	.95	S.	N.	W.	.46	S. 15 E.	690
61	14	Geneva, Switzerland	46 12	6 8 E.	1,338	2.551	.90	NE.	SW.	SSW.	.46	S. 26 E.	560
62	Aug. 3	Cambridge, England	52 12	0 8 E.	8[illegible]	3.180	.86	E.	SE.	WSW.	.63	N. 28 E	150
63	17	Barcelona, Spain .	41 23	2 15 E.	138	2.908	.99	SE.	SSW.	S.	.82	N. 78 E.	310
64	18	Gratz, Austria	47 4	15 28 E.	1,171	3.544	.86	NE.	SE.	NW.	.58	S. 78 E.	627
65	Sept. 15	Marseilles, France.	43 18	5 23 E.	246	3.051	.88	SE.	E.	ESE.	.82	S. 35 E.	230
66	16	Marseilles, France.	43 18	5 23 E.	246	6.261	.91	E.	ESE.	NW.	.84	S. 36 E.	373
67	25	Avignon, France..	43 57	4 48 E.	65	5.836	30.09	E.	N.	N.	.96	North.	200
68	25	Milan, Italy	45 28	9 11 E.	482	2.599	29.99	NE.	E.	NE.	.96	N. 32 E.	360
69	25	Christiania, Norway.....	59 55	10 45 E.	134	3.083	.86	SSE.	SSW.	SW.	.68	S. 58W.	280
70	26	Pola, Austria	44 52	13 51 E.	105	2.962	.85	SSE.	WSW.	SSW.	.83	N. 44 E.	250
71	Oct. 29	San Fernando, Spain	36 28	6 13W.	95	3.183	.78	S.	SE.	W.	.65	S. 15 E.	460
72	Nov. 20	Genoa, Italy.....	44 24	8 55 E.	157	3.165	.88	NW.	NE.	NE.	.78	N. 45 E.	140
73	Dec. 4	Genoa, Italy.....	44 24	8 55 E.	157	2.539	.53	NE.	N.	Calm.	28.99	S. 74 E.	660
74	15	Bergen, Norway ..	60 24	5 20 E.	56	2.500	30.29	SSE.	SE.	S.	29.34	S. 64 E.	900
	1880.												
75	Jan. 18	Lons Le Saulnier, France	46 40	5 33 E.	853	2.680	29.99	SSW.	SW.	W.	.85	N. 20W.	224
76	Feb. 11	Chartres, France .	48 26	1 31 E.	524	3.540	.71	E.	N.	S.	.69	*	0
77	11	Genoa, Italy.....	44 24	8 55 E.	157	4.186	.87	NE.	N.	N.	.69	S. 47 E.	470
78	16	Santiago, Spain .	42 53	8 28W.	863	3.760	.07	SW.	SSW.	SSW.	28.43	S. 14 E.	476
79	Mar. 2	Kiel, Germany ...	54 19	10 4 E.	13	2.858	.34	SW.	SW.	WSW.	.56	S. 37 E.	566
80	Apr. 3	Pic du Midi, France	42 16	0 8 E.	7,763	3.582	30.11	NNW.	S.	W.	29.95	S. 73W.	250
81	27	Pic du Midi, France	42 16	0 8 E.	7,763	2.634	29.76	SE.	NNE.	NE.	.55	N. 80W.	277
82	May 7	Pic du Midi, France	42 16	0 8 E.	7,763	4.824	.80	NE.	W.	N.	.47	West.	470
83	12	Perpignan, France	42 42	2 53 E.	105	3.820	.77	S.	NE.	NE.	.73	S. 45 E.	120
84	June 11	Rochefort, France.	45 56	0 58W.	29	4.670	.94	SE.	WSW.	SW.	-----	-----	-----
85	14	Rochefort, France.	45 56	0 58W.	29	3.460	30.08	E.	W.	SW.	-----	-----	-----
86	Aug. 3	Valona, Turkey ..	40 27	19 27 E.	105	2.680	29.81	SW.	W.	NW.	.44	S. 47 E.	423
87	22	Le Mans, France .	48 1	0 12 E.	285	2.811	.95	E.	NNE.	NE.	.79	N. 66W.	325
88	23	Rochefort, France.	45 56	0 58W.	29	2.870	.96	SW.	WSW.	SW.	-----	-----	-----
89	29	Moncalieri, Italy .	45 0	7 41 E.	846	2.894	.98	WSW.	N.	NE.	.84	N. 20 E.	490
90	31	Pesaro, Italy	43 55	12 53 E.	46	2.965	30.04	NE.	N.	NW.	.88	N. 9W.	226
91	Sept. 7	Flushing, Netherlands	51 24	3 35 E.	0	2.787	.03	WSW.	NW.	E.	.77	N. 70W.	72
92	8	Szathmar, Austria.	47 46	22 53 E.	430	2.519	29.86	W.	SW.	NW.	.58	S. 9W.	569
93	9	Genoa, Italy.....	44 24	8 55 E.	157	3.536	.96	SE.	SE.	SW.	.89	*	0
94	13	Udine, Italy.....	46 4	13 13 E.	381	2.850	.87	Calm.	Calm.	S.	.76	N. 59 E.	220
95	16	Rochefort, France.	35 56	0 58W.	29	2.990	.87	WNW.	W.	W.	-----	-----	-----
96	28	Syracuse, Italy ...	37 3	15 15 E.	72	2.875	.87	E.	ENE.	E.	.87	*	0
97	Oct. 4	Brest, France.....	48 24	4 30W.	210	2.579	.49	NE.	WSW.	WNW.	.19	N. 71 E.	425
98	14	Valona, Turkey ..	40 27	19 27 E.	105	2.760	.95	S.	E.	SE.	.84	S. 87 E.	300
99	15	Valona, Turkey ..	40 27	19 27 E.	105	3.860	.92	E.	SE.	NW.	.84	S. 72 E.	69
100	29	Lisbon, Portugal .	38 42	9 8W.	312	3.082	.99	SW.	WSW.	SW.	.78	South.	290
101	Nov. 3	Marseilles, France.	43 18	5 23 E.	246	3.552	.41	SE.	E.	WNW.	.41	N. 40 E.	120
102	4	Pola, Austria	44 52	13 51 E.	105	3.071	.95	ENE.	E.	W.	.84	N. 55 E.	555
103	4	Puy de Dome, France	45 46	2 58 E.	4,813	2.578	.97	E.	ENE.	NNE.	.84	N. 15W.	386
104	16	Rochefort, France.	45 56	0 58W.	29	3.150	.52	W.	S.	SW.	-----	-----	-----
105	Dec. 27	Santiago, Spain ..	42 53	8 28W.	863	2.854	.83	SW.	S.	SW.	.12	S. 10 E.	600
106	28	Santiago, Spain ..	42 53	8 28W.	863	2.661	.78	S.	SW.	WNW.	.44	S. 7W.	580

Table CXXVI shows all the stations at which a rainfall of 2½ inches in 24 hours was reported more than once. The table also shows the number of cases of heavy rain at each of the stations:

TABLE CXXVI.—*Number of cases of heavy rain at each station.*

Station.	Lat.	Elevation.	Cases.	Station.	Lat.	Elevation.	Cases.	Station.	Lat.	Elevation.	Cases.
	° ′	*Feet.*			° ′	*Feet.*			° ′	*Feet.*	
Trieste	45 39	85	10	Rochefort	45 56	79	5	Marseilles	43 18	246	3
Genoa	44 24	157	8	Pic du Midi	42 15	7,763	4	Nottingham	52 57	174	2
Valona	40 27	105	7	Puy de Dome	45 46	4,813	3	Nismes	43 51	188	2
Udine	46 4	381	6	Moncalieri	45 0	846	3	Rome	41 54	164	2
Santiago	42 53	863	6	Pola	44 52	105	3				

266. The cases of heavy rain reported at Rochefort are believed to be erroneous. They all occurred in the 6 months from June to November, 1880, and during this period the amount of rain at Rochefort reported in the International Bulletin is many times greater than is given in the official report of the French Meteorological Bureau. The error is supposed to have resulted from the fact that the rainfall was measured in tenths of a millimetre, but was reported in such a way that in the Signal Service Office the numbers were understood to represent millimetres, thus making the rainfall ten times too great. Of the other 13 stations all but 1 are in the south of Europe, and show unequivocally the influence of local causes, 2 of the stations being on mountains, and the others being in the neighborhood of mountains where the mean anuual rainfall is unusually great. Of the whole number of stations having a rainfall of 2½ inches in 24 hours, 86 are situated south of latitude 48° and 15 north of latitude 48°, indicating that in Europe south of the parallel of 48°, heavy rains are about six times as frequent as they are north of that parallel. This conclusion is not, however, fully warranted, because the stations of observation are not distributed uniformly over Europe, and because the rainfall was not reported from Russia and Denmark, and only occasionally from Great Britain.

A rainfall of 2½ inches in 24 hours is, however, of extremely rare occurrence in European Russia north of latitude 46°. This is shown by Professor Wild's Regen Verhältnisse des Russischen Reiches. From this work I have derived Table CXXVII, showing in column 7 the number of cases in which as much as 2½ inches of rain in 24 hours were observed at 16 stations during the period of years given in column 6.

TABLE CXXVII.—*Rainfall of 2½ inches in 24 hours in European Russia.*

No.	Station.	Lat.	Long.	Elevation.	Years.	Cases.	No.	Station.	Lat.	Long.	Elevation.	Years.	Cases.
		° ′	° ′	*Feet.*					° ′	° ′	*Feet.*		
1	Kem	64 57	34 39	33	18	0	9	Simbirsk	54 19	48 24	459	12	2
2	Kronstadt	59 59	29 47	66	34	1	10	Gorki	54 17	30 59	689	32	1
3	St. Petersburg	59 56	30 16	20	44	0	11	Warschau	52 13	21 1	392	40	2
4	Reval	59 26	24 45	0	27	0	12	Orenburg	51 46	55 7	361	32	0
5	Kostroma	57 47	40 55	261	12	0	13	Kiew	50 26	30 31	591	23	4
6	Riga	56 57	24 6	33	30	0	14	Lugan	48 35	39 20	188	43	1
7	Libau	56 30	21 1	33	21	2	15	Nikolaew	46 58	31 58	62	23	0
8	Moskau	55 46	37 40	448	27	0	16	Astrachan	46 21	48 2	68	33	0

This table indicates that in 3 years, at the 15 international stations of European Russia, only one case of 2½ inches rainfall in 24 hours is to be expected.

In order to obtain further information from Great Britain I have consulted the British observations at stations of the second order for the 3 years in question, and have found but 5 cases in which there was a rainfall of 2½ inches in 24 hours.

The following are the cases:

TABLE CXXVIII.—*Rainfall of 2½ inches in 24 hours at British stations of the second order.*

Date.	Station.	Lat.	Long,	Elevation.	Rain.
1878.		° ′	° ′	*Feet.*	*Inches.*
June 30	Chigwell Row.....	51 37	0 6 E.	186	2.750
Sept. 7	Hereford	52 5	2 45 W.	274	2.750
1879.					
June 30	Dartmoor	50 33	3 59 W.	1,359	2.890
1880.					
Jan. 29	Laudale.....	56 41	5 41 W.	14	2.740
Oct. 27	Dublin	53 20	6 15 W.	51	2.736

In 1878 the number of British stations of the second order was 33; in 1879 it was 36, and in 1880 it was 40. This comparison indicates that the conclusion above stated must be nearly correct, viz, that in Europe south of the parallel of 48° heavy rains occur about six times as frequently as they do north of that parallel.

For the 15 cases of Table CXXV north of the parallel of 48°, the average height of the barometer at the center of the low area with which the great rainfall seemed to be associated was 29.51 inches, and the average distance of the rain station from the low center was 308 miles. For the 86 cases south of the parallel of 48°, the average height of the barometer at the center of the low area with which the great rainfall seemed to be associated was 29.50 inches, and the average distance of the rain station from the low center was 375 miles. For the cases south of latitude 48° the average distance of the rain station from the low center was decidedly greater than for cases north of latitude 48°, although a considerable number of the former cases have been referred to a subordinate barometric depression when there was a much more important depression situated at a distance exceeding 500 miles.

TABLE CXXIX.—*Winds accompanying heavy rains at Trieste.*

No.	Date.	Moncalieri.	Mondovi.	Milan.	Leghorn.	Florence.	Padua.	Rome.
	1878.							
1	Apr. 24	NNW.	SW.	NE.	S.	SE.	NNE.	S.
2	May 8	W.	NW.	E.	W.	WSW.	SW.	W.
3	25	SSE.	NE.	NE.	S.	SW.	ENE.	S.
4	June 5	SSE.	N.	SW.	WSW.	W.	E.	W.
5	15	SSW.	ENE.	N.	W.	SW.	SE.	W.
6	July 26	SSW.	NW.	.....	W.	WSW.	NNE.	W.
7	30	NE.	NE.	.....	SW.	W.	SE.	S.
8	Sept. 15	SW.	NW.	SE.	SSW.	SE.	ENE.	W.
9	20	NW.	N.	ESE.	WSW.	NW.	SE.	SSW.
10	24	NNW.	NW.	E.	SSW.	E.	NE.	S.
11	Oct. 9	SE.	N.	E.	SW.	ENE.	E.	W.
12	14	SSE.	W.	W.	SW.	WNW.	ENE.	S.
13	21	NNW.	NW.	ENE.	SE.	SE.	N.	SW.
14	Nov. 14	NE.	SE.	W.	NE.	SW.	S.	W.
15	Dec. 17	ENE.	Calm.	NE.	NE.	N.	N.	S.
	1879.							
16	Jan. 2	ESE.	NE.	W.	W.	SW.	NW.	W.
17	30	ENE.	NW.	SSE.	ENE.	W.	NE.	NW.
18	Feb. 15	NNW.	WSW.	NNE.	S.	SE.	NE.	SW.
19	Mar. 23	W.	NW.	SE.	W.	E.	NE.	S.
20	26	E.	W.	ESE.	NE.	SE.	NNE.	S.
21	27	SSE.	NNW.	S.	ESE.	NW.	NNE.	S.
22	Apr. 16	ENE.	SW.	E.	S.	E.	N.	W.
23	Aug. 17	WSW.	NW.	ESE.	S.	S.	SE.	W.
	1880.							
24	July 31	NNW.	WNW.	S.	SSE.	S.	NNW.	S.
25	Sept. 20	ENE.	NE.	ESE.	.....	SSE.	E.	SSW.
26	Dec. 18	N.	WNW.	N.	NE	ENE.	N.	SSE.

TABLE CXXIX.—*Winds accompanying heavy rains at Trieste*—Continued.

No.	Date.	Pesaro.	Udine.	Trieste.	Pola.	Krems-munster.	Gratz.	Agram.	Vienna.
	1878.								
1	Apr. 24	E.	E.	ENE.	SE.	SE.	SW.	SE.	SSE.
2	May 8	W.	S.	SW.	SSW.	W.	NW.	SW.	Calm.
3	25	SE.	S.	SE.	SE.	WNW.	SW.	SW.	S.
4	June 5	SW.	SE.	Calm.	SSE.	W.	SSW.	NE.	W.
5	15	S.	SW.	E.	S.	WSW.	ESE.	NE.	SW.
6	July 26	NE.	N.	ESE.	Calm.	W.	E.	NW.	SW.
7	30	E.	Calm.	NW.	SE.	W.	NE.	NE.	SW.
8	Sept. 15	W.	Calm.	Calm.	NE.	Calm.	E.	NE.	NE.
9	20	NE.	.....	W.	SE.	Calm.	SW.	NE.	SE.
10	24	.....	E.	SSE.	SE.	W.	S.	NE.	SSE.
11	Oct. 9	.....	E.	Calm.	SSE.	Calm.	E.	NE.	SSE.
12	14	NW.	NE.	ENE.	ENE.	ENE.	ENE.	NE.	NE.
13	21	E.	Calm.	Calm.	S.	ENE.	S.	SW.	ESE.
14	Nov. 14	NW.	N.	SW.	SSE.	W.	NE.	NE.	E.
15	Dec. 17	W.	NE.	Calm.	SSE.	Calm.	S.	SW.	Calm.
	1879.								
16	Jan. 2	S.	Calm.	Calm.	S.	WNW.	WNW.	NW.	W.
17	30	N.	SE.	ENE.	ENE.	ENE.	SSE.	E.	Calm.
18	Feb. 15	SE.	NE.	E.	SE.	NE.	WSW.	E.	SSE.
19	Mar. 23	N.	SE.	Calm.	SE.	E.	SW.	SE.	NNE.
20	26	E.	E.	S.	SE.	ENE.	S.	E.	SSE.
21	27	NW.	E.	E.	W.	ENE.	E.	E.	SE.
22	Apr. 16	N.	SW.	N.	SE.	NE.	WSW.	SW.	E.
23	Aug. 17	SE.	SE.	E.	S.	W.	NE.	SW.	W.
	1880.								
24	July 31	NE.	SW.	N.	SE.	WSW.	S.	NE.	W.
25	Sept. 20	S.	SW.	SW.	SSW.	WNW.	SE.	NE.	SSW.
26	Dec. 18	S.	SW.	Calm.	SSE.	ESE.	SSW.	E.	SSE.

267. The great rainfalls in Southern Europe were generally included in a low area whose center was 300 miles or more from the rain station. Occasionally the rain station was less than 200 miles from the low center; but it was seldom that the international observations showed any sensible barometric depression in the immediate neighborhood of the rain station. There was, however, generally a cyclonic movement of the winds in the neighborhood of the rain station. In many cases this cyclonic movement was very distinctly marked; in some cases the cyclonic movement was not very obvious, but there is reason to believe that it would have been perceptible if the stations of observation had been sufficiently numerous. Table CXXIX exhibits this cyclonic character of the winds in the neighborhood of a great rainfall. The table includes all the cases in which there was a rainfall of 2 inches in 24 hours at Trieste, during the 3 years under examination, and the table shows the direction of the winds at 13 of the international stations nearest to Trieste.

In each one of these cases there was a decided cyclonic motion of the winds about a center generally less than 200 miles from Trieste. In some cases there was apparently more than one center of local cyclonic movement. In No. 2 the cyclonic motion is distinctly shown, but the center of the cyclonic movement was nearly 200 miles east of Trieste, and only the western half of the cyclonic system is shown by the observations in the table.

In one-third of the cases in Table CXXIX the depression of the barometer attending the cyclonic movement of the winds is distinctly shown by the international observations; but in about two-thirds of the cases the depression was quite small, sometimes not exceeding one or two hundredths of an inch. If the stations of observation had been more numerous, it is probable that a somewhat greater barometric depression would have been indicated.

268. Another station where heavy rains frequently occur is the Pic du Midi, and in these cases there is generally a cyclonic movement of the winds in that vicinity. Most frequently the center of the system appears to be near the eastern portion of the Pyrenees. This is seen from Table CXXX which gives all the cases in which a rainfall of 2 inches in 24 hours was reported at the Pic du Midi during the 3 years under examination.

TABLE CXXX.—*Winds accompanying heavy rains on Pic du Midi.*

No.	Date.	Bourgos.	Madrid.	Bilbao.	Tarbes.	Pic du Midi.	Toulouse.	Mont Louis.	Barcelona.	Carcassonne.	Perpignan.	Nismes.	Marseilles.
	1878.												
1	Mar. 25	NE.	NW.	NW.	WSW.	NW.	WNW.	WSW.	NE.	W.	NW.	NW.	NW.
2	Dec. 2	N.	NW.	NW.	.....	NNE.	WNW.	SW.	WNW.	E.	N.	N.	
	1879.												
3	Jan. 6	SW.	SW.	NW.	W.	N.	NW.	NW.	E.	NW.	NE.	N.	
4	Jan. 7	SW.	SW.	NW.	SSW.	N.	W.	WNW.	E.	NE.	E.	N.	
5	Apr. 3	SW.	W.	NW.	W.	NW.	W.	W.	SE.	W.	NE.	N.	WNW.
6	Apr. 4	N.	NW.	NW.	W.	N.	NW.	NW.	S.	W.	N.	N.	NW.
	1880.												
7	Apr. 3	SW.	NW.	SW.	NW.	S.	W.	WSW.	S.	W.	NE.	N.	SW.
8	Apr. 27	N.	NW.	NW.	W.	NNE.	N.	WNW.	E.	WNW.	NW.	N.	ESE.
9	May. 6	N.	NE.	NW.	W.	NE.	SE.	WNW.	S.	E.	NW.	NW.	SSE.
10	May. 7	N.	N.	NW.	W.	W.	NNW.	W.	SSW.	W.	NW.	NW.	NW.
11	Sept. 20	SW.	S.	NW.	W.	W.	NW.	WSW.	SSE.	W.	NE.	SE.	NW.

In 9 of these cases there is decided evidence of a cyclonic movement of the winds about a center near the east end of the Pyrenees. In Nos. 1 and 10 the evidence of cyclonic motion about a center near the Pyrenees is not very clear; but in No. 1 there was a strongly marked system of cyclonic winds whose center was not far from Nice; and in No. 10 there was a strongly marked system of cyclonic winds whose center was not far from Corsica. In 3 of the cases there was a decided center of low pressure within 200 miles of the Pyrenees. In the other cases the depression of the barometer near the center of the cyclonic system was slight.

269. That the heavy rains enumerated in Table CXXV were generally attended by a cyclonic movement of the winds is proved by columns 9, 10, and 11, which show the changes in the direction of the wind during the continuance of the rain. In 14 cases the wind changed 180° during the progress of the rain; in 40 cases the wind changed 135°; and in nearly two-thirds of the cases the change was as great as 90°. There were only 2 cases in which there was no change in the wind's direction during these two days, viz, Nos. 6 and 7. In No. 6 there was a large area of low pressure over the Atlantic Ocean, which remained nearly stationary for 48 hours, and this seems to have been the cause of the steady east winds at Greenwich, although there was a slight local depression of the barometer not far from Greenwich. In No. 7 the steady northwest winds at Moncalieri must have been due to local causes, for at all the neighboring international stations during these two days there were considerable changes of the wind amounting generally to more than 90°.

The distribution of the cases in Table CXXV by seasons was as follows:

Winter, 19; spring, 19; summer, 21; and autumn, 42.

We see that these cases of heavy rain are distributed more uniformly through the different months of the year than they are in the United States; but they are decidedly most frequent in the autumn, corresponding in this respect with heavy rains in the northern part of the United States.

In the cases shown in Table CXXV the rain center was generally on the east side of the low center, as is shown by the following summary.

	Cases.		Cases.		Cases.
In the NE quadrant,	20	In the NW quadrant,	16	Directly east,	1
SE quadrant,	38	Directly north,	3	Directly west,	1
SW quadrant,	12	Directly south,	1	The two centers coincident,	9

This summary appears to indicate that in Europe great rains occur on the west side of the low center more frequently than they do in the United States. A part of this difference can be ascribed to the fact that the reported rainfall covers a period of 24 hours, and the position of the rain center deduced from the observations was its position 12 hours previous to the date of the barometric observation. In this time the low center generally advances 200 miles, so that in those cases in which the direction of the rain center from the low center is given as nearly north or

south, the direction if corrected for 12 hours motion would become easterly. The rain center must have been on the east side of the low center in about three fourths of the cases, which does not differ greatly from what we have found for the United States.

RAIN OVER THE NORTH ATLANTIC OCEAN.

270. If we could have similar observations of the rainfall over all parts of the Atlantic Ocean they would be of great value in determining the dependence of rainfall upon barometric pressure. As such observations have never been made, I have sought for the best available information bearing upon this question. This I have derived from the Atlantic weather charts, from August 1, 1882, to September 3, 1883, published under the authority of the British Meteorological Council. These maps show for each day the region where showers prevailed and where rain prevailed. I have arranged in Table CXXXI all the cases in which there is marked upon these maps a rain area over 600 English statute miles in length (omitting the tropical regions); and in order to exhibit more clearly the character of the results I have divided the cases into seven groups. Group A contains 29 cases in which the center of the rain area coincided nearly with a center of low pressure; Group B contains 161 cases in which the rain was associated with an area of low pressure, chiefly on its eastern side; Group C contains 46 cases in which the rain center was almost exactly north or south of a center of low pressure; Group D contains 54 cases in which the rain was associated with an area of low pressure chiefly on its western side; Group E contains 25 cases in which the rain was partly over an area of low pressure, and partly over an area of high pressure, being about equally divided between them; Group F contains 22 cases in which the rainfall was accompanied by a barometric pressure above 30 inches, and the rain area was situated between two areas of high pressure; group G contains 38 cases in which the rain fell chiefly over an area of high pressure, and was not distinguished by the peculiarity of Group F.

TABLE CXXXI.—*Rain over the North Atlantic Ocean.*

A.—THE CENTER OF A RAIN AREA COINCIDES NEARLY WITH A CENTER OF LOW PRESSURE.

No.	Date.	Dimensions, Eng. statute miles.	Low bar.	Rain from low.	No.	Date.	Dimensions, Eng. statute miles.	Low bar.	Rain from low.	No.	Date.	Dimensions, Eng. statute miles.	Low bar.	Rain from low.
	1882.					1883.					1883.			
1	Sept. 8	1,000– 890	29.8	.....	10	Jan. 10	1,910– 815	29.1	.....	20	June 28	652– 377	29.4	.....
2	10	875– 360	29.7	.....	11	12	1,100– 480	28.8	.....	21	July 6	670– 352	29.7	.....
3	16	820– 566	29.1	.....	12	29	1,850– 500	29.8	.....	22	9	1,295– 386	29.8	.....
4	Oct. 23	1,830– 490	28.9	.....	13	Feb. 12	944– 446	29.5	.....	23	11	823– 206	29.9	.....
5	24	910– 430	29.4	.....	14	28	1,380– 600	29.7	.....	24	28	832– 370	29.5	.....
6	Nov. 23	1,100– 924	29.1	.....	15	Mar. 5	1,587– 770	29.7	.....	25	Aug. 1	627– 224	29.9	.....
7	Dec. 16	1,560– 625	29.3	.....	16	17	1,115– 550	29.6	.....	26	11	746– 360	29.3	.....
8	24	1,220– 455	29.1	.....	17	Apr. 19	703– 352	29.6	.....	27	14	1,013– 257	29.3	.....
	1883.				18	May 7	1,235– 770	29.4	.....	28	27	1,184– 274	29.4	.....
9	Jan. 7	823– 700	29.7	.....	19	29	987– 180	29.3	.....	29	Sept. 1	746– 670	28.3	.....

B.—RAIN ASSOCIATED WITH AN AREA OF LOW PRESSURE, CHIEFLY ON ITS EASTERN SIDE.

	1882.						1882.						1882.			
30	Aug. 12	652– 360	29.4	SE.	44	Sept. 9	815– 377	28.8	SE.	58	Oct. 10	712– 600	29.1	SE.
31	18	800– 240	29.3	East.	45	11	1,140– 625	29.4	NE.	59	13	1,000– 265	29.0	East.
32	25	823– 400	29.0	NE.	46	12	900– 445	29.4	SE.	60	14	2,800– 410	29.4	SE.
33	26	790– 283	29.8	East.	47	13	944– 435	29 4	SE.	61	16	1,450– 343	29.4	East.
34	27	950– 283	29.7	NE.	48	14	1,010– 172	29.1	East.	62	17	1,530– 460	28.8	NE.
35	29	1,166– 274	29.6	NE.	49	15	830– 470	29.1	East.	63	18	1,460– 480	28.5	East.
36	30	1,115– 257	29.4	East.	50	16	700– 580	29.1	NE.	64	19	700– 257	29.7	NE.
37	31	1,600– 412	29.2	NE.	51	22	1,160– 900	29.1	East.	65	20	910– 446	28.7	East.
38	31	600– 430	29.2	SE.	52	27	1,250– 386	29.7	NE.	66	20	1,310– 454	28.7	SE.
39	Sept. 1	900– 815	28.9	East.	53	28	1,370– 455	29.0	NE.	67	22	1,270– 280	28.8	NE.
40	2	1,490– 360	29.3	SE.	54	Oct. 1	1,610– 875	28.4	NE.	68	23	800– 377	29.8	NE.
41	3	780– 230	29.4	East.	55	6	788– 430	29.4	SE.	69	29	884– 370	29.0	NE.
42	4	690– 386	29.6	NE.	56	7	800– 694	29.4	NE.	70	Nov. 2	800– 460	28.8	NE.
43	7	935– 240	29.4	SE.	57	10	635– 370	29.1	NE.	71	2	1,115– 400	28.9	SE.

TABLE CXXXI.—*Rain over the North Atlantic Ocean*—Continued.

B.—RAIN ASSOCIATED WITH AN AREA OF LOW PRESSURE, CHIEFLY ON ITS EASTERN SIDE—continued.

No.	Date.	Dimensions, Eng. statute miles.	Low bar.	Rain from low.	No.	Date.	Dimensions, Eng. statute miles.	Low bar.	Rain from low.	No.	Date.	Dimensions, Eng. statute miles.	Low bar.	Rain from low.
	1882.					1883.					1883.			
72	Nov. 10	858–430	29.2	NE.	111	Mar. 18	1,012–386	29.5	NE.	151	June 2	686–200	29.7	East.
73	11	635–395	29.4	NE.	112	23	1,209–497	29.2	East.	152	12	875–352	29.6	East.
74	14	1,175–800	28.9	East.	113	26	1,742–686	29.1	NE.	153	12	1,141–558	29.3	SE.
75	14	730–370	29.4	SE.	114	27	1,115–755	29.2	NE.	154	21	627–275	29.4	SE.
76	15	918–566	28.9	SE.	115	28	970–892	29.1	East.	155	23	618–240	29.6	NE.
77	18	978–532	29.1	SE.	116	29	2,282–686	28.7	East.	156	29	772–446	29.4	NE.
78	19	1,010–395	28.8	SE.	117	29	1,140–1,013	29.4	East.	157	30	1,004–600	29.3	NE.
79	22	960–460	29.1	East.	118	30	1,425–703	28.1	East.	158	30	978–480	29.3	SE.
80	23	1,250–446	29.0	NE.	119	31	600–265	28.5	NE.	159	July 2	944–283	29.4	NE.
81	27	820–550	29.2	SE.	120	31	790–343	28.5	SE.	160	8	755–343	29.6	SE.
82	Dec. 2	1,040–515	28.8	East.	121	Apr. 1	978–695	28.9	SE.	161	9	780–755	28.7	SE.
83	3	1,050–700	28.7	NE.	122	1	1,287–515	29.5	East.	162	10	661–308	28.8	East.
84	4	1,355–790	29.0	NE.	123	2	1,227–455	28.7	SE.	163	10	1,218–360	29.8	East.
85	5	1,010–500	29.4	NE.	124	3	858–832	29.4	East.	164	12	892–644	29.5	SE.
86	13	900–670	28.5	SE.	125	4	823–343	28.3	East.	165	13	884–558	29.8	East.
87	17	1,050–325	29.1	NE.	126	8	695–497	29.5	SE.	166	15	944–198	29.8	East.
88	20	772–625	29.3	NE.	127	13	772–618	28.7	East.	167	17	600–198	29.9	East.
	1883.				128	15	1,14 –832	28.9	East.	168	25	712–257	29.3	East.
89	Jan. 3	960–400	28.6	SE.	129	17	1,613–892	28.3	NE.	169	28	686–257	29.6	East.
90	12	1,570–660	29.4	NE.	130	18	884–343	29.8	East.	170	28	627–257	29.6	SE.
91	13	1,115–386	27.9	SE.	131	19	627–351	28.5	NE.	171	Aug. 3	703–275	29.7	SE.
92	17	985–300	28.5	East.	132	20	806–275	29.5	SE.	172	7	1,175–369	29.6	SE.
93	18	712–420	29.4	SE.	133	21	798–627	29.1	East.	173	12	1,647–515	28.8	NE.
94	31	970–450	29.1	NE.	134	22	840–490	29.7	NE.	174	12	798–190	29.7	NE.
95	Feb. 6	920–400	28.3	SE.	135	23	2,570–463	29.6	East.	175	13	1,056–627	29.1	NE.
96	7	1,270–500	28.2	NE.	136	24	815–395	29.7	East.	176	13	618–487	29 8	East.
97	8	1,400–470	28.3	SE.	137	29	652–463	29.5	NE.	177	14	978–566	29.4	SE.
98	14	1,050–455	27.4	NE.	138	May 1	790–283	29.5	East.	178	15	1,304–806	29.0	SE.
99	17	815–325	28.8	SE.	139	6	618–403	29.6	NE.	179	16	644–369	30.0	East.
100	19	2,127–455	28.3	SE.	140	10	1,400–918	29.0	SE.	180	17	840–455	29.5	East.
101	21	652–498	29.7	SE.	141	11	1,227–377	29.2	SE.	181	18	858–446	29.3	SE.
102	27	1,252–995	29.0	SE.	142	13	1,004–223	29.0	SE.	182	19	987–686	29.1	SE.
103	Mar. 1	892–394	29.2	East.	143	16	695–257	29.4	NE.	183	20	627–377	29.2	NE.
104	3	600–377	29.7	SE.	144	18	1,115–96	29.5	NE.	184	21	755–283	29.5	East.
105	7	970–703	29.5	SE.	145	20	1,132–610	29.2	East.	185	22	772–480	29.5	SE.
106	8	661–515	29.3	SE.	146	20	1,115–618	29.6	NE.	186	25	1,056–377	29.3	East.
107	10	600–497	28.9	SE.	147	24	703–566	29.7	SE.	187	30	944–412	29.3	East.
108	11	1,030–575	28.9	SE.	148	25	944–386	29.3	SE.	188	31	970–661	29.1	NE.
109	12	840–429	28.9	SE.	149	27	1,098–541	29.2	East.	189	Sept. 1	652–627	29.9	East.
110	14	790–489	29.3	SE.	150	28	1,012–386	29.0	NE.	190	3	1,321–438	29.4	SE.

C.—RAIN CENTER ALMOST EXACTLY NORTH OR SOUTH OF LOW CENTER.

	1882.					1883.					1883.			
191	Sept. 6	820–377	29.3	South.	206	Feb. 13	3,650–1,300	27.6	South.	222	Apr. 24	600–472	29.6	North.
192	8	970–455	29.2	South.	207	16	1,700–1,123	28.6	South.	223	25	902–352	29.4	South.
193	11	970–735	29.5	North.	208	18	858–300	28.0	South.	224	25	1,141–498	29.7	South.
194	19	875–580	29.2	South.	209	26	892–472	28.8	South.	225	26	1,544–463	28.9	South.
195	23	1,000–386	29.1	South.	210	26	678–206	29.1	South.	226	27	970–265	28.8	North.
196	Oct. 22	1,250–257	29.9	North.	211	Mar. 1	815–498	29.2	South.	227	27	927–283	29.7	South.
197	25	1,485–300	29.1	North.	212	6	1,141–601	29.2	South.	228	28	703–190	28.9	South.
198	26	1,115–610	29.3	South.	213	14	1,287–412	29.7	South.	229	May 6	798–265	29.8	North.
199	Nov. 27	772–470	29.5	South.	214	16	1,561–532	29.2	South.	230	24	970–429	29.0	South.
200	Dec. 17	1,130–335	29.1	North.	215	17	875–532	29.5	North.	231	30	644–283	29.5	South.
201	22	1,080–438	29.0	North.	216	22	644–541	29.0	North.	232	June 1	670–446	29.8	North.
	1883.				217	25	1,252–403	28.8	South.	233	26	995–257	29.5	North.
202	Jan. 10	892–257	29.2	North.	218	30	618–360	28.1	South.	234	Jnly 21	712–437	30.0	South.
203	11	686–250	29.0	South.	219	31	2,059–429	29.1	South.	235	26	627–172	29.4	South.
204	Feb. 2	920–300	28.6	North.	220	Apr. 2	1,485–823	28.5	South.	236	Aug. 25	686–198	29.3	South.
205	9	2,574–1,250	27.9	South.	221	15	910–583	29.9	North.					

TABLE CXXXI.—*Rain over the North Atlantic Ocean*—Continued.

D.—RAIN ASSOCIATED WITH AN AREA OF LOW PRESSURE, CHIEFLY ON ITS WESTERN SIDE.

No.	Date.	Dimensions, Eng. statute miles.	Low bar.	Rain from low.	No.	Date.	Dimensions, Eng. statute miles.	Low bar.	Rain from low.	No.	Date.	Dimensions, Eng. statute miles.	Low bar.	Rain from low.
	1882.					1883.					1883.			
237	Aug. 11	1,310– 360	29.3	SW.	255	Feb. 20	755– 394	28.6	SW.	274	May 5	1,528– 266	29.6	SW.
238	20	686– 340	29.1	SW.	256	22	987– 352	28.6	SW.	275	27	737– 300	29.2	NW.
239	Sept. 5	1,210– 610	29.2	SW.	257	Mar. 4	902– 377	29.1	SW.	276	June 9	703– 265	29.7	SW.
240	5	772– 257	29.2	West.	258	6	840– 369	29.1	West.	277	15	644– 550	29.8	NW.
241	10	995– 410	29.3	SW.	259	7	627– 412	29.1	West.	278	17	635– 257	29.8	West.
242	27	686– 530	29.3	NW.	260	9	600– 326	29.3	West.	279	27	1,030– 291	29.4	SW.
243	Oct. 11	670– 360	29.1	SW.	261	11	627– 352	29.0	West.	280	28	772– 437	29.5	NW.
244	22	695– 430	28.8	NW.	262	12	627– 360	29.2	West.	281	July 13	815– 232	29.2	NW.
245	30	944– 395	29.4	SW.	263	21	720– 308	29.5	West.	282	29	952– 369	29.7	West.
246	Nov. 4	644– 515	29.5	NW.	264	23	823– 480	28.8	West.	283	30	652– 463	29.9	SW.
247	8	978– 395	28.8	SW.	265	24	618– 498	28.8	NW.	284	Aug. 6	703– 343	29.7	West.
248	21	1,130– 566	29.4	SW.	266	24	610– 360	28.8	SW.	285	11	806– 283	29.3	SW.
249	22	858– 550	29.1	NW.	267	27	806– 343	29.2	West.	286	15	627– 274	29.4	SW.
250	24	858– 700	28.8	West.	268	28	1,184– 532	29.2	SW.	287	23	910– 618	29.4	NW.
	1883.				269	Apr. 13	644– 455	28.7	SW.	288	25	652– 224	29.5	SW.
251	Jan. 9	823– 430	29.4	SW.	270	14	703– 377	28.7	SW.	289	28	610– 283	29.3	SW.
252	30	2,600– 532	29.3	SW.	271	16	670– 463	29.1	SW.	290	29	1,493– 386	29.5	SW.
253	Feb. 6	875– 584	28.3	SW.	272	16	600– 257	29.1	SW.					
254	15	1,150– 815	28.0	SW.	273	26	772– 377	29.9	West.					

E.—RAIN ABOUT EQUALLY DIVIDED BETWEEN AREAS OF HIGH AND LOW PRESSURE.

	1882.					1882.					1883.			
291	Aug. 1	652– 430	....	.....	300	Dec. 18	800– 455	....	.....	309	May 2	772– 446	....	.....
292	6	800– 618	....	.....		1883.				310	3	661– 541	....	.....
293	19	918– 308	....	.....	301	Jan. 21	960– 395	....	.....	311	8	995– 232	....	.....
294	Sept. 25	832– 430	....	.....	302	23	866– 480	....	.....	312	9	600– 429	....	.....
295	Oct. 4	1,210– 635	....	.....	303	Feb. 7	755– 350	....	.....	313	16	729– 326	....	.....
296	Nov. 39	678– 360	....	.....	304	Apr. 5	1,150– 317	....	.....	314	25	1,621– 403	....	.....
297	Dec. 1	1,740– 480	....	.....	305	6	1,141– 308	....	.....	315	31	790– 360	....	.....
298	6	746– 472	....	.....	306	7	720– 532	....	.....					
299	9	1,010– 575	....	.....	307	7	644– 550	....	.....					
					308	12	772– 264	....	.....					

F.—RAIN AREA SITUATED BETWEEN TWO HIGH AREAS, WITH PRESSURE ABOVE 30 INCHES.

	1882.					1883.					1883.			
316	Aug. 21	1,510– 275	....	.....	324	Feb. 21	644– 386	....	.....	331	Mar. 19	1,845– 755	....	.....
317	Nov. 17	1,000– 300	....	.....	325	23	618– 403	....	.....	332	20	661– 524	....	.....
	1883.				326	Mar. 7	832– 566	....	.....	333	21	635– 429	....	.....
318	Jan. 14	1,630– 370	....	.....	327	9	1,175– 618	....	.....	334	Apr. 21	670– 369	....	.....
319	20	746– 240	....	.....	328	9	1,201– 412	....	.....	335	22	686– 215	....	.....
320	Feb. 2	1,350– 532	....	.....	329	10	824– 627	....	.....	336	May 12	1,021– 386	....	.....
321	9	635– 257	....	.....	330	18	1,115– 627	....	.....	337	July 18	610– 257	....	.....
322	13	1,630– 460	....	.....										
323	19	746– 369	....	.....										

TABLE CXXXI.—*Rain over the Norlh Atlantic Ocean*—Continued.

G.—RAIN WITHIN AN AREA OF HIGH PRESSURE AND DISTINCT FROM GROUP F.

No.	Date.	Dimensions, Eng. statute miles.	Bar. rain center.	Near Gulf Stream.	No.	Date.	Dimensions, Eng. statute miles.	Bar. rain center.	Near Gulf Stream.	No.	Date.	Dimensions, Eng. statute miles.	Bar. rain center.	Near Gulf Stream.
	1882.					1883.					1883.			
338	Aug. 7	712– 435	30.06	No.	351	Jan. 26	660– 283	30.35	Yes.	364	May 14	720– 283	30.25	Yes.
339	23	772– 352	30.06	Yes.	352	31	1,210– 695	30.05	Yes.	365	15	927– 360	30.05	No.
340	Sept. 9	1,370– 370	30.10	Yes.	353	Feb. 4	1,000– 480	30.18	Yes.	366	17	772– 558	30.05	No.
341	21	790– 435	30.03	Yes.	354	6	650– 400	30.10	Yes.	367	27	780– 403	30.20	No.
342	Oct. 5	920– 850	30.20	Yes.	355	11	830– 377	30.40	Yes.	368	31	729– 446	30.10	Yes.
343	Nov. 5	700– 280	30.15	No.	356	28	926– 703	30.10	No.	369	June 27	858– 265	30.10	Yes.
344	Dec. 2	1,570– 815	30.10	No.	357	Mar. 8	858– 446	30.23	Yes.	370	29	635– 343	30.20	Yes.
	1883.				358	20	627– 275	30.12	No.	371	July 15	1,047– 326	30.05	Yes.
345	Jan. 2	644– 420	30.17	Yes.	359	Apr. 4	653– 294	30.20	No.	372	Aug. 1	670– 308	30.05	Yes.
346	4	772– 343	30.06	No.	360	6	635– 352	30.15	No.	373	9	627– 190	30.15	Yes.
347	5	858– 700	30.22	Yes.	361	7	661– 412	30.14	No.	374	10	712– 240	30.05	No.
348	6	738– 400	30.10	Yes.	362	May 4	686– 308	30.10	Yes.	375	Sept. 1	806– 240	30.10	Yes.
349	23	730– 455	30.14	Yes.	363	5	618– 472	30.05	No.					
350	24	730– 352	30.09	Yes.										

In this table, column 3 shows the extreme length and br eadth of the rain areas expressed in English statute miles; column 4 shows, for the first four groups, the barometric pressure at the center of the low area with which the rain area was ass ociated, and column 5 shows the general direction of the rain center from the center of low pre ssure. In Group G, column 4 shows the height of the barometer at the center of the rain area, and column 5 shows the relation of the rain area to the Gulf Stream. Those cases in which the rain area was so near to the Gulf Stream as to be supposed to be influenced by it, are marked *yes*, while the other cases are marked *no*. It is, however, probable that in some of the latter cases the vapor which was precipitated was partly derived from the Gulf Stream.

271. We see that these great rain areas are found in all months of the year.

TABLE CXXXII.—*Number of cases of great rain for each month.*

Month.	Num-ber.	Month.	Num-ber.	Month.	Num-ber.	Month.	Num-ber.
December	16	March	51	June	18	September	30
January	26	April	42	July	23	October	26
February	32	May	35	August	37	November	22
Winter	74	Spring	128	Summer	78	Autumn	78

In Table CXXXII, column 2 shows the number of cases for each month of the year. This table indicates that over the North Atlantic Ocean great rains occur most frequently in the spring of the year, especially in the month of March.

These rain areas sometimes have very great extent, there being 120 cases in which the rain area was at least 1,000 English statute miles in length; 29 cases in which it was at least 1,500 miles in length; 8 cases in which it was at least 2,000 miles in length; and 5 cases in which the rain area was over 2,500 miles in length. These 5 cases were Nos. 60, 135, 205, 206, and 252. It must not be supposed that in these cases the directions given in column 5 of Table CXXXI are applicable to the entire length of the rain area. In No. 60 more than one third of the entire length was within an area of low pressure on its southeast side; then followed about an equal distance between two areas of high pressure; and the remainder was within a second area of low pressure. A similar statement is applicable to No. 252. No. 135 was mainly associated with a low area, 29.6 inches; but partly with a second low area, 29.8 inches. Nos. 205 and 206 extended beyond the area of low pressure into an area of high pressure.

The number of rain areas associated with areas of low pressure chiefly on the eastern side (Group B) is 161; and the number chiefly on the western side (Group D) is 54. The former number is three times the latter. If, however, in this comparison, we include Group A, and consider half of these cases as situated on the east side of the low center, and the other half on the west side, we shall have on the east side 176 cases, and on the west side 68 cases; which numbers are in the ratio of 2.6 to 1.

272. Rain with barometric pressure somewhat above 30 inches is unexpectedly prevalent over the Atlantic Ocean; there being 38 cases in which the rain center was associated with a pressure above 30 inches; 17 cases in which the rain center was associated with a pressure above 30.1 inches; and 5 cases in which the rain center was associated with a pressure above 30.2 inches, the highest being 30.4 inches. There were also 25 cases (Group E) in which the rain was about equally divided between areas of high and low pressure. Similar cases sometimes occur in the United States, where great rain areas frequently extend somewhat beyond the isobar 30 inches. Table CVIII furnishes 7 cases in which the station of greatest rain showed a pressure exceeding 30 inches, the highest being 30.16 inches. Table CX furnishes 19 cases in which the station of greatest rain showed a pressure exceeding 30 inches, the highest being 30.18 inches. Table CXIII furnishes 5 cases, in which the station of greatest rain showed a pressure exceeding 30 inches, the highest being 30.11 inches. The accompanying plates furnish examples illustrating these statements. Plate XL, Fig. 1, shows a rain-area of 1 inch, with barometer 30.11 inches. Plate XLVI, Fig. 1, shows an area of rain amounting to 0.99 inch at the center, with barometer 30.11 inches. In both of these cases, the rain center was a center of feeble cyclonic motion, which did not much affect the barometer.

Two-thirds of the cases enumerated in Table CXXXI, Group G, were so near to the Gulf Stream that this stream may be presumed to have had an important influence on the rainfall. The 5 cases in Group G, in which the rain center was associated with a pressure exceeding 30.2 inches, were all near the Gulf Stream, and appear to have been similar to cases in the United States. In No. 351 there was an area of high pressure (30.5 inches) on the northwest side of the rain area, with a temperature of —20° F. From this high area strong northerly winds pushed down to the Gulf Stream where there was a lower pressure, and the water had a temperature of +45° F. This cold air pushed under the warmer air of the Gulf Stream, elevating it to a height sufficient to condense its vapor. Nos. 357 and 347 were similar to No. 351.

In No. 364 there was a high area (30.5 inches) on the southeast side of the rain area, and low pressure (29.4 inches) on the north side. The winds were southerly, and as they contained a large amount of vapor from the Gulf Stream they ascended from the earth's surface in consequence of feeble specific gravity. In No. 355 there was a high area (30.5 inches) on the east side, and a low pressure (29.7 inches) on the west side. The winds were southeasterly, and the result was the same as in No. 364.

We see that over the Atlantic Ocean the air does not always descend from the upper regions over every part of an area of high pressure. Over some portion of an area of high pressure the air frequently ascends; and this appears to take place when the air contains an unusual amount of aqueous vapor.

273. A comparison of the results now obtained will suggest some important conclusions respecting the influence of local causes in modifying the relation of rainfall to barometric pressure. We have found that in the United States east of the Rocky Mountains—

(1) South of latitude 36°, a rainfall of $2\frac{1}{2}$ inches in 8 hours at any station occurs on the east side of a low area more frequently than on the west side, in the ratio of 2.6 to 1 (see Table CX).

(2) North of latitude 36°, a rainfall of 2 inches in 8 hours at any station occurs on the east side of a low area more frequently than on the west side, in the ratio of 2.8 to 1 (see Table CVIII).

(3) A total rainfall of 9 inches in 8 hours at all the stations east of the Rocky Mountains occurs on the east side of a low area more frequently than on the west side, in the ratio of 6.2 to 1 (see Table CXIII).

(4) Over the North Atlantic Ocean great rain areas occur on the east side of an area of low pressure more frequently than on the west side, in the ratio of 2.6 to 1 (see Table CXXXI).

(5) In Europe a rainfall of 2½ inches in 24 hours at any station occurs on the east side of a low area more frequently than on the west side, in the ratio of 2 to 1 (see Table CXXV).

These results indicate that in the United States and Europe, as well as over the North Atlantic Ocean, great rainfalls are generally associated with a barometric pressure somewhat below the mean, and the precipitation occurs chiefly on the eastern side of a low area. We notice, however, considerable discordances which may be ascribed to the different modes of comparison which have been adopted. In No. 1, a center of low pressure was compared with the station of greatest rainfall, when the rainfall amounted to at least 2½ inches in 8 hours. In No. 2, a center of low pressure was compared with the station of greatest rainfall, when the rainfall amounted to at least 2 inches in 8 hours. In No. 5, a center of low pressure was compared with the station of greatest rainfall, when the rainfall amounted to at least 2½ inches in 24 hours. In No. 3, a center of low pressure was compared with the station of greatest rainfall, when the total rainfall at all the stations east of the Rocky Mountains was unusually great. In No. 4, the amount of rainfall is entirely unknown, but the center of a great rain area is compared with the center of a neighboring area of low pressure.

The principal discordances in the results (1–5) can not be ascribed to the different modes of comparison adopted, but must be due to some other cause. The great excess of rain centers on the east side of the low center in No. 3, may reasonably be ascribed to the influence of the Atlantic Ocean with its Gulf Stream, furnishing an inexhaustible supply of vapor; and the comparatively small number of rain centers on the east side of the low center in Europe may be ascribed to the influence of the dry air in the interior of the continent.

Rain with a rising or falling barometer.

274. The preceding results have been derived from a comparison of rainfalls of unusual magnitude. It is not safe to conclude that the same results would be derived from a comparison of the aggregate rainfall for an entire year at each station, since small rainfalls may be subject to a law somewhat different from those of extraordinary magnitude. There is another mode of comparison which takes account of the total rainfall at any station. Generally, on the preceding side (which is usually the eastern side) of a low center, the barometer is falling, and on the following side (which is usually the western side) the barometer is rising. The mode of comparison consists in determining the total amount of rain which comes during the year with a falling barometer, and also that which comes with a rising barometer, and finding the ratio of these two amounts. In order to render the method entirely satisfactory, we require hourly observations of the rainfall as well as of the barometer. I have found very few stations where the rainfall has been measured hourly or even bi-hourly. In most meteorological journals, the rainfall is recorded but once a day. Such observations are of no value for the present purpose. The following are the best materials I have found suitable for this comparison.

(1) Observations made at Girard College, Philadelphia, from 1840 to 1845. For three years the observations were made hourly, and for the other year once in two hours. (2) Hourly observations at seven stations in Great Britain and Ireland, viz, Valencia, Armagh, Glasgow, Aberdeen, Falmouth, Stonyhurst and Kew, for 1874. (3) Observations eight times a day at Paris for 1877. (4) Observations once in two hours at Brussels for 1879. (5) Hourly observations at Prague for 1865, 1866 and 1869. (6) Hourly observations at Vienna for 1854, 1855 and 1856. (7) Hourly observations at Pawlowsk, near St. Petersburg, for one year.

For the Signal Service observations, in which the rain is measured three times a day, we may determine the time of least pressure from the tri-daily weather maps, and distribute the rain accordingly under the two heads of falling and rising barometer. This method can not give accurate results, but may furnish useful information in the absence of hourly observations. The results which I have obtained are shown in Table CXXXIII, and are all expressed in English inches. When the observations at any station were continued more than one year, the average rainfall for all the years, has been taken. I have inserted the results for one Signal Service station, viz, Indianapolis, Ind.

The first column under each station shows the monthly fall of rain while the barometer was descending, and the second column shows the fall of rain while the barometer was rising. At the bottom of the table is shown the total rainfall for the year, and the last line shows the ratio of the total numbers in the two columns.

TABLE CXXXIII.—*Rainfall with a rising or falling barometer.*

Months.	Indianapolis, two years.		Philadelphia, four years.		Valencia, one year.		Armagh, one year.		Falmouth, one year.		Kew, one year.		Stonyhurst, one year.	
	Falling.	Rising.	Falling.	Rising.	Falling.	Rising.	Falling.	Rising.	Falling.	Rising.	Falling.	Rising.	Falling.	Rising.
January	2.81	0.84	2.36	0.42	2.90	2.04	1.46	0.49	3.52	2.92	0.53	0.43	3.38	1.54
February	1.76	2.40	1.20	0.29	3.62	1.46	1.64	0.31	2.95	0.85	0.82	0.29	1.11	0.63
March	3.64	2.16	2.06	0.33	1.65	1.01	0.08	0.49	0.89	0.76	0.22	0.21	6.26	0.95
April	3.10	1.34	2.34	0.97	2.64	1.31	0.88	0.70	1.83	0.83	1.04	0.22	1.15	0.49
May	1.84	0.78	1.95	0.58	0.60	0.44	0.91	0.18	0.15	0.21	0.33	0.27	0.65	0.98
June	2.73	2.47	2.22	0.58	0.93	0.53	0.46	0.37	1.85	0.87	1.55	0.99	1.16	0.35
July	1.30	2.18	2.03	2.63	3.31	1.65	0.22	0.70	1.15	0.56	0.88	0.39	1.97	1.07
August	1.72	1.14	3.98	1.39	4.03	1.27	2.05	1.75	2.93	0.67	1.04	0.24	3.95	3.07
September	1.48	0.63	1.67	0.50	4.14	2.23	1.96	1.20	4.04	1.96	2.07	0.73	3.38	2.09
October	0.15	0.20	1.43	0.52	5.28	1.96	2.60	1.04	5.01	1.60	2.00	1.72	3.69	2.95
November	2.63	2.16	2.60	0.48	3.45	1.08	2.12	0.76	3.84	0.76	1.52	0.62	3.19	1.40
December	0.91	1.87	3.19	0.68	5.17	2.06	1.91	0.91	6.44	2.66	1.12	0.42	2.81	0.85
Year	24.07	18.17	27.03	9.37	37.72	17.04	17.29	8.90	35.50	14.65	13.12	6.53	31.70	16.37
Ratio	1.32		2.88		2.21		1.94		2.42		2.01		1.94	

Months.	Glasgow, one year.		Aberdeen, two years.		Paris, one year.		Brussels, one year.		Pawlowsk, one year.		Prague, three years.		Vienna, three years.	
	Falling.	Rising.	Falling.	Rising.	Falling.	Rising.	Falling.	Rising.	Falling.	Rising.	Falling.	Rising.	Falling.	Rising.
January	2.13	1.18	1.69	0.29	1.55	0.56	1.61	0.55	0.90	0.51	0.30	0.27	0.88	0.42
February	0.53	0.28	1.33	0.54	0.55	0.37	1.59	1.56	0.04	0.15	0.78	0.46	0.57	0.58
March	2.24	0.70	1.37	1.55	0.51	0.15	0.30	0.50	0.44	0.06	0.80	0.86	0.12	0.22
April	1.02	0.72	0.77	0.56	0.83	1.45	1.52	0.90	0.17	0.45	0.31	0.55	0.08	0.32
May	1.99	0.50	0.79	0.67	0.00	0.00	0.76	0.53	0.89	1.04	0.47	0.76	1.13	1.02
June	0.63	0.15	0.85	0.31	2.58	1.94	1.02	2.79	0.43	1.32	1.00	1.34	1.04	1.09
July	2.69	0.99	1.93	0.85	1.68	1.07	1.93	2.82	1.10	1.24	0.63	1.41	0.42	2.26
August	3.14	1.24	2.77	1.76	0.64	0.64	1.26	2.32	2.68	3.01	0.60	1.16	1.10	1.45
September	2.50	1.50	0.90	0.92	1.61	0.47	0.81	0.35	1.44	0.98	0.10	0.52	0.47	1.02
October	5.57	1.62	1.14	1.11	0.71	0.87	0.87	0.36	0.15	0.32	0.10	0.48	0.49	0.42
November	2.61	1.15	2.27	1.25	0.28	0.09	0.71	1.11	1.27	0.45	0.76	0.53	1.30	0.52
December	1.66	0.41	1.03	1.35	0.59	0.15	0.66	0.75	1.41	0.77	0.57	0.41	0.73	0.35
Year	26.71	10.44	16.84	11.16	11.53	7.76	13.04	14.54	10.92	10.30	6.42	8.75	8.33	9.67
Ratio	2.56		1.51		1.49		0.90		1.06		0.73		0.86	

275. If we group together those stations which seem most intimately related we shall obtain the following results, showing the ratio of the amount of precipitation which comes with a falling barometer compared with that which comes with a rising barometer:

Indianapolis, Ind	1.32 to 1	Paris and Brussels	1.19 to 1
Philadelphia, Pa	2.88 to 1	Pawlowsk, Russia	1.06 to 1
Seven British stations	2.08 to 1	Prague and Vienna	0.80 to 1

These results exhibit a remarkable accordance, and point distinctly to the operation of a general cause. They are similar to those obtained in article 273, but are much more definite. At Philadelphia the amount of rain which falls while the barometer is descending is nearly three times as great as that which falls while the barometer is rising; and during the six colder months of the year the rainfall in the former case is nearly five times as great as in the latter case. In summer thunder showers frequently occur with an abundant fall of rain, accompanied by a slight rise of the barometer, and this explains the fact that in July there is more rain with a rising than with a falling barometer. The entire Atlantic coast of the United States, north of latitude 36°, exhibits results similar to those found for Philadelphia.

As we advance westward from the Atlantic coast the ratio of the precipitation when the barometer is falling, compared with that when the barometer is rising, changes somewhat rapidly, and before we reach the Mississippi River the ratio is reduced to 1.32. These results indicate that the great excess of rain on the eastern side of areas of low pressure near the Atlantic coast is due to the fact that on the eastern side they have the Gulf Stream, which furnishes an inexhaustible supply of vapor.

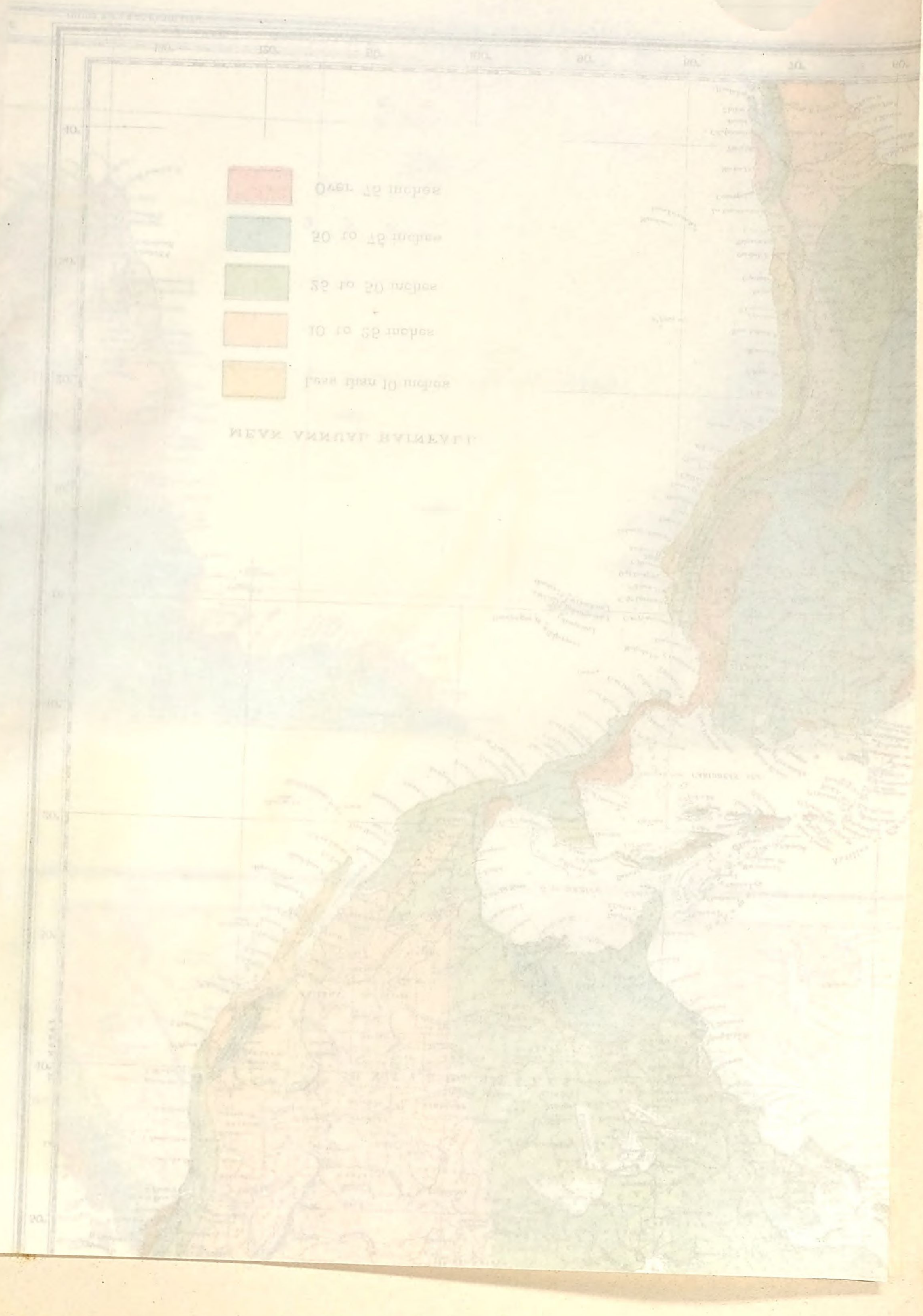
In Great Britain the amount of rain with a falling barometer is twice that with a rising barometer; but as we advance eastward this ratio rapidly diminishes, and in central Europe the precipitation is greater when the barometer is rising than when it is falling. This result is due to the fact that in central Europe areas of low pressure have a comparatively dry air on their eastern side, and there is a more liberal supply of vapor on the western than on the eastern side. Hence we conclude that the amount of rainfall on the eastern side of an area of low pressure depends largely upon the direction and distance of the principal supply of aqueous vapor.

MEAN ANNUAL RAIN-FALL FOR THE DIFFERENT COUNTRIES OF THE GLOBE.

PLATE XXXIII.



JULIUS BIEN & CO. PHOTO. LITH.

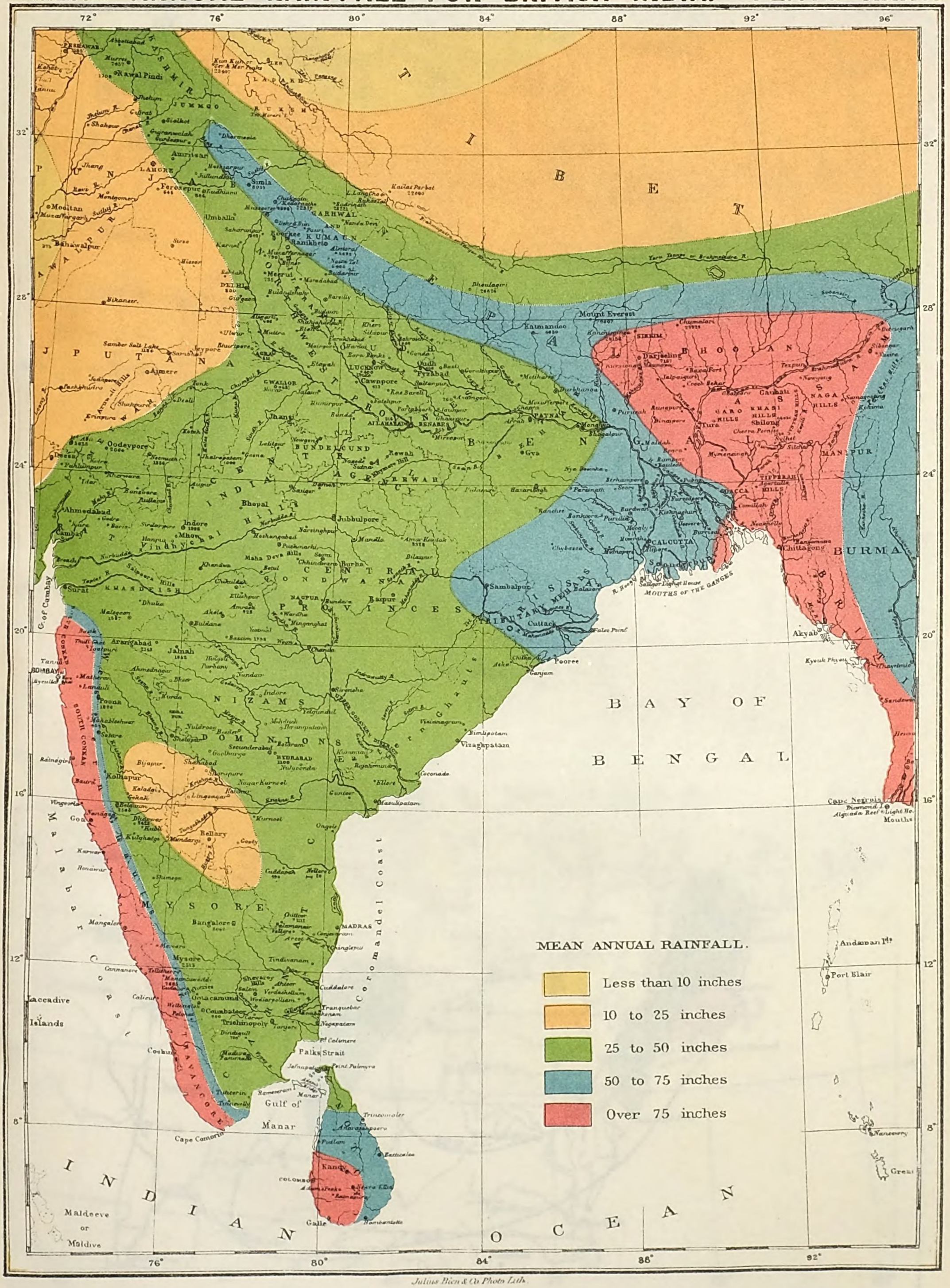


MEAN ANNUAL RAIN-FALL FOR CALIFORNIA. PLATE XXXIV.

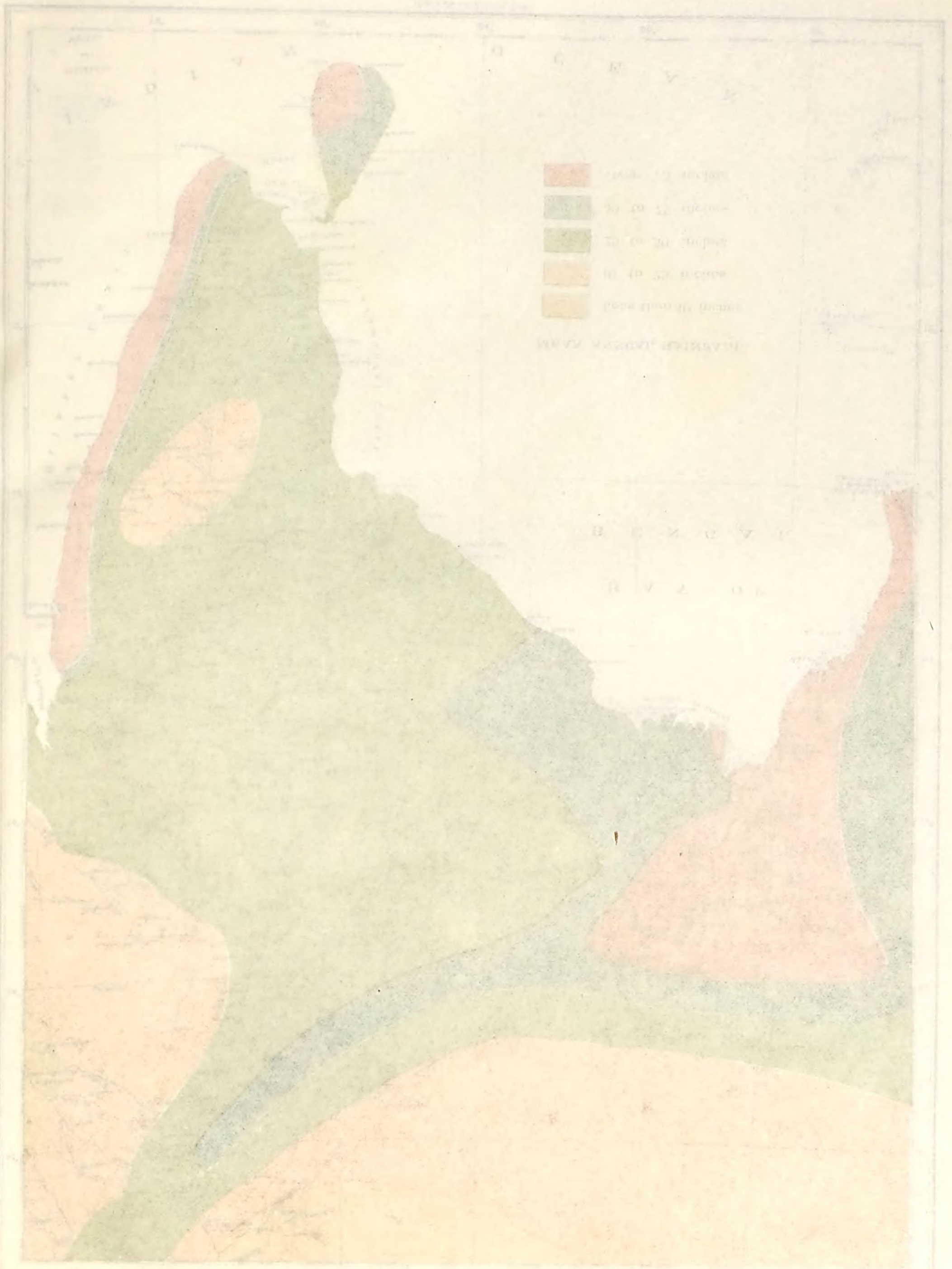


Julius Bien & Co. Photo Lith.

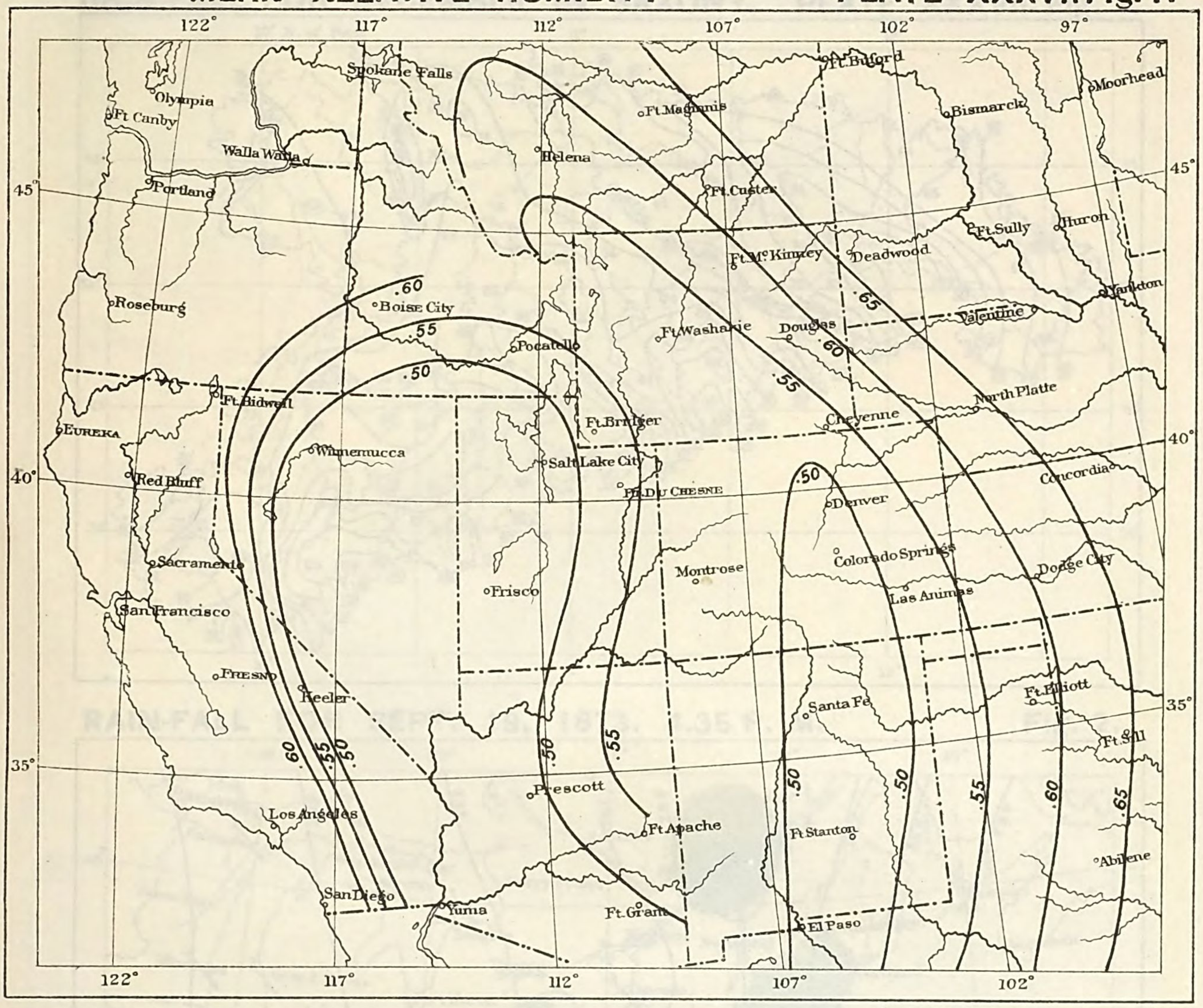
MEAN ANNUAL RAIN-FALL FOR BRITISH INDIA. PLATE XXXV.



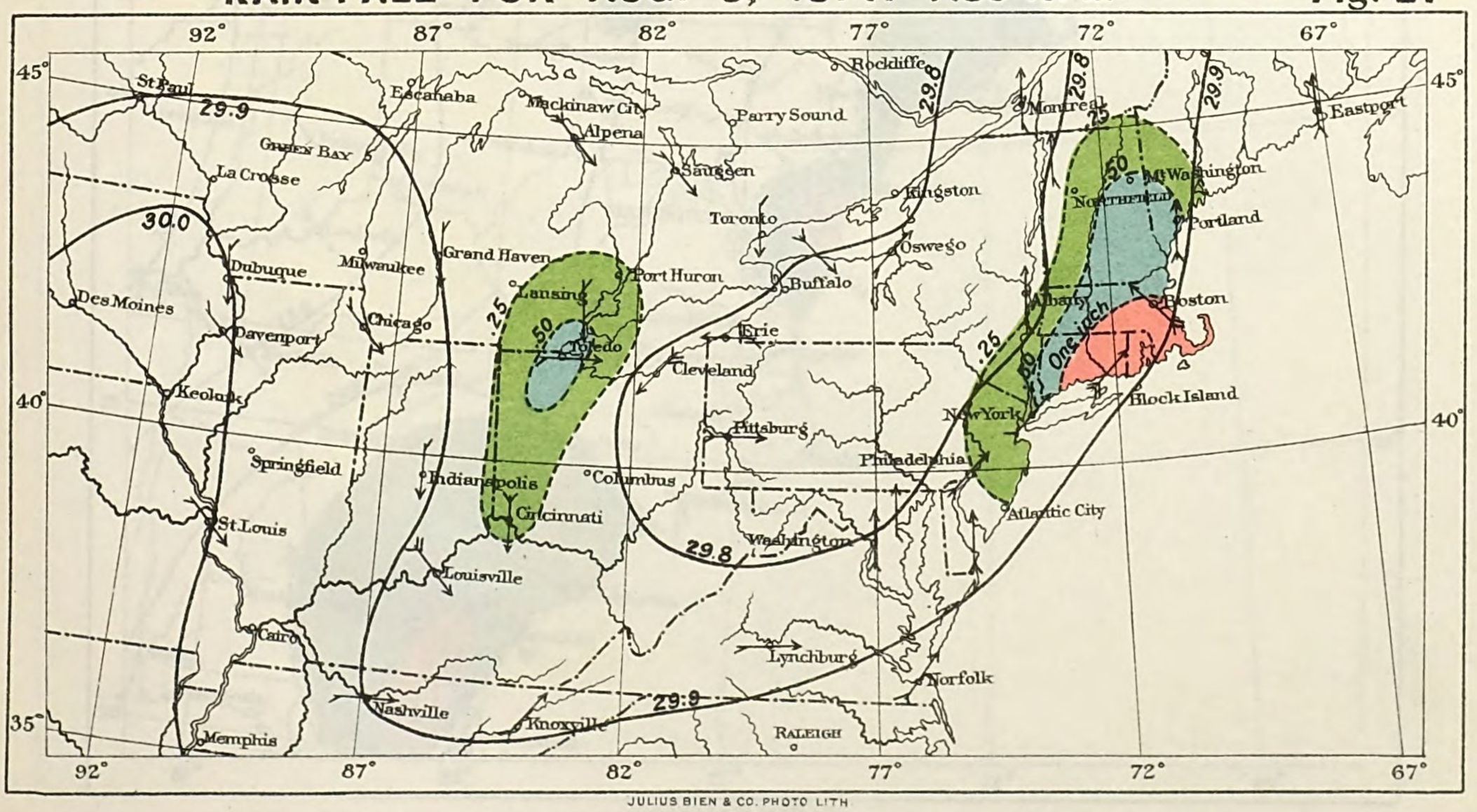
Julius Bien & Co Photo Lith.



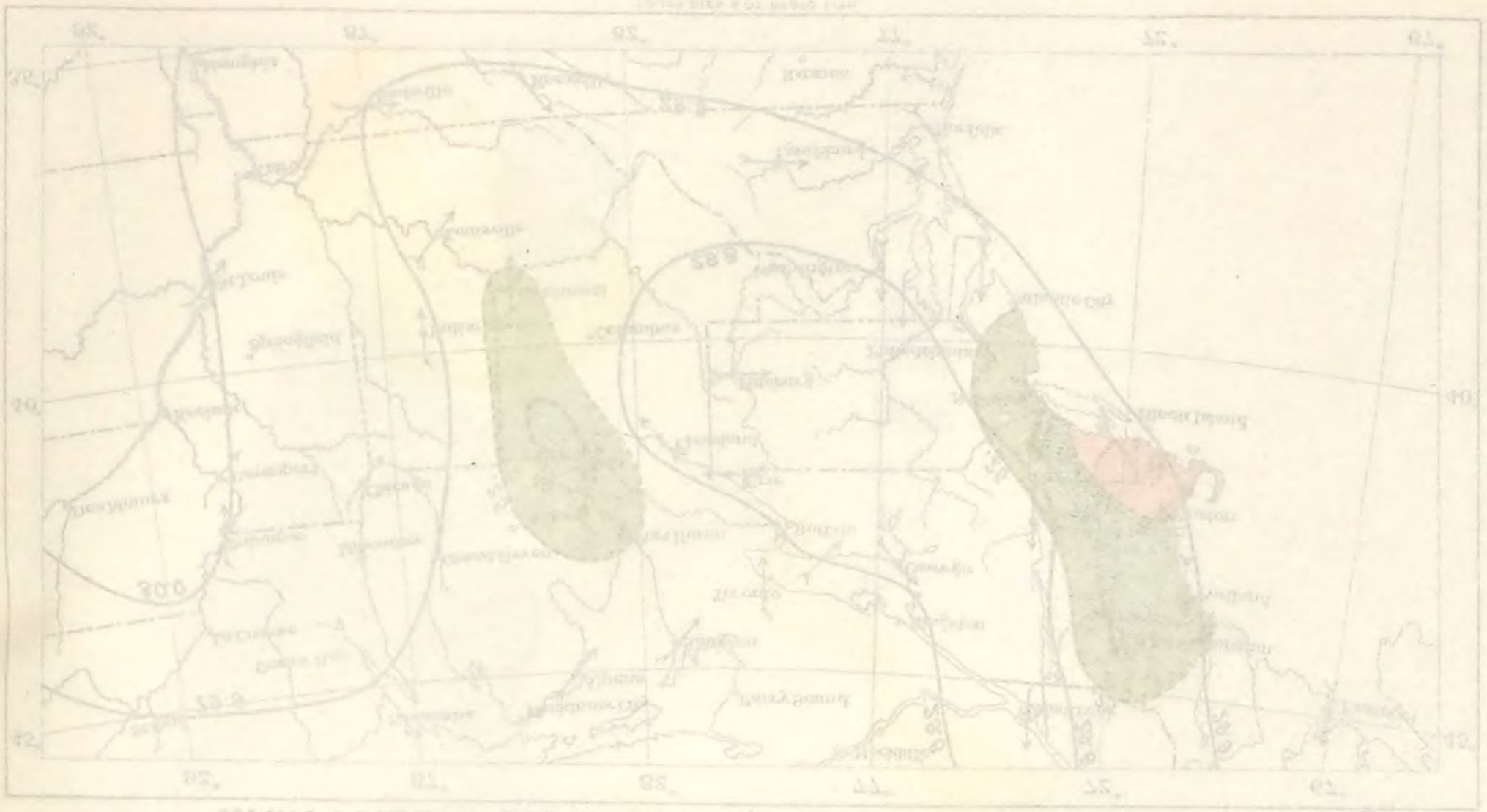
MEAN RELATIVE HUMIDITY — PLATE XXXVI. Fig. 1.



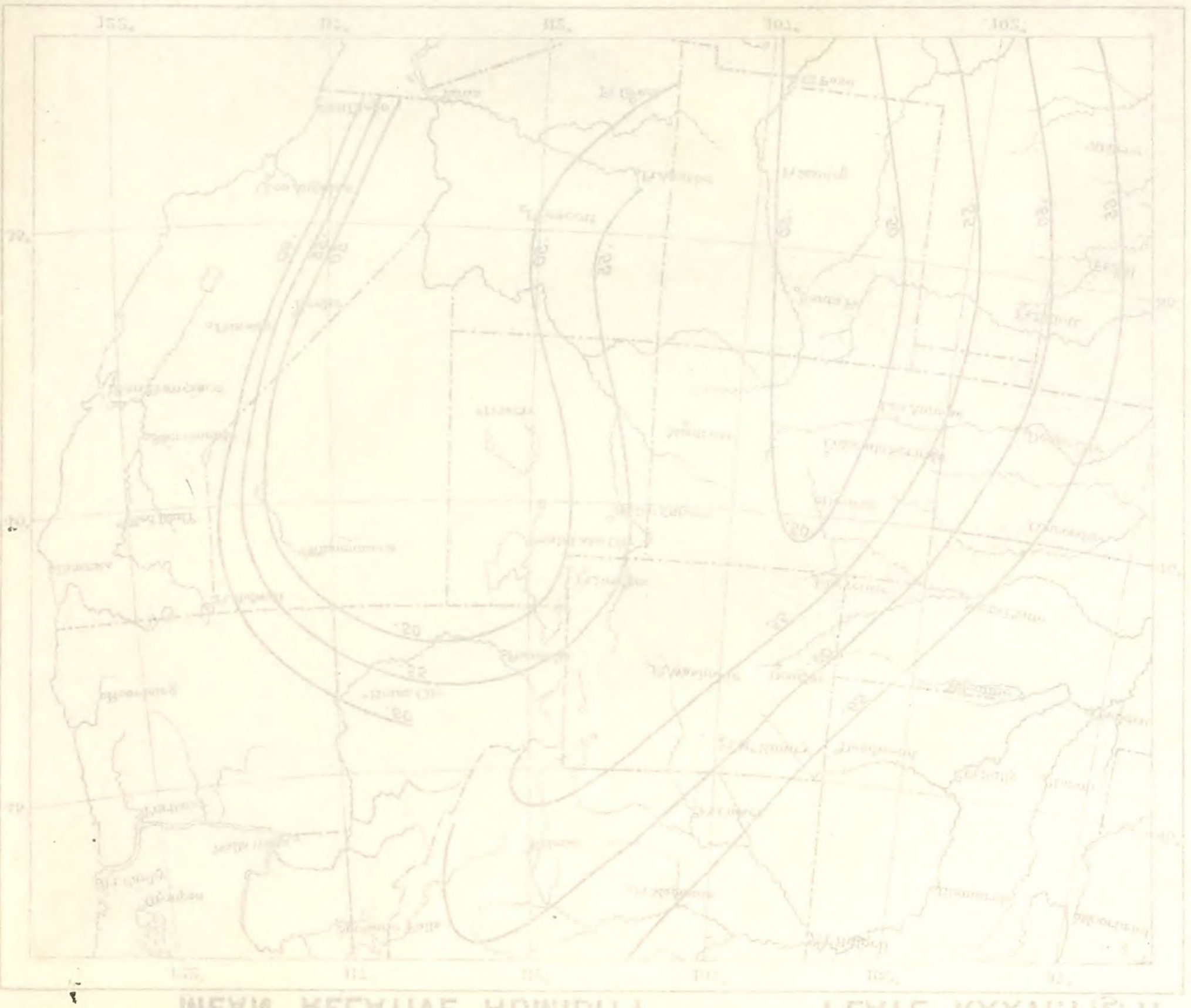
RAIN-FALL FOR AUG. 8, 1874. 7.35 A. M. — Fig. 2.



JULIUS BIEN & CO. PHOTO LITH

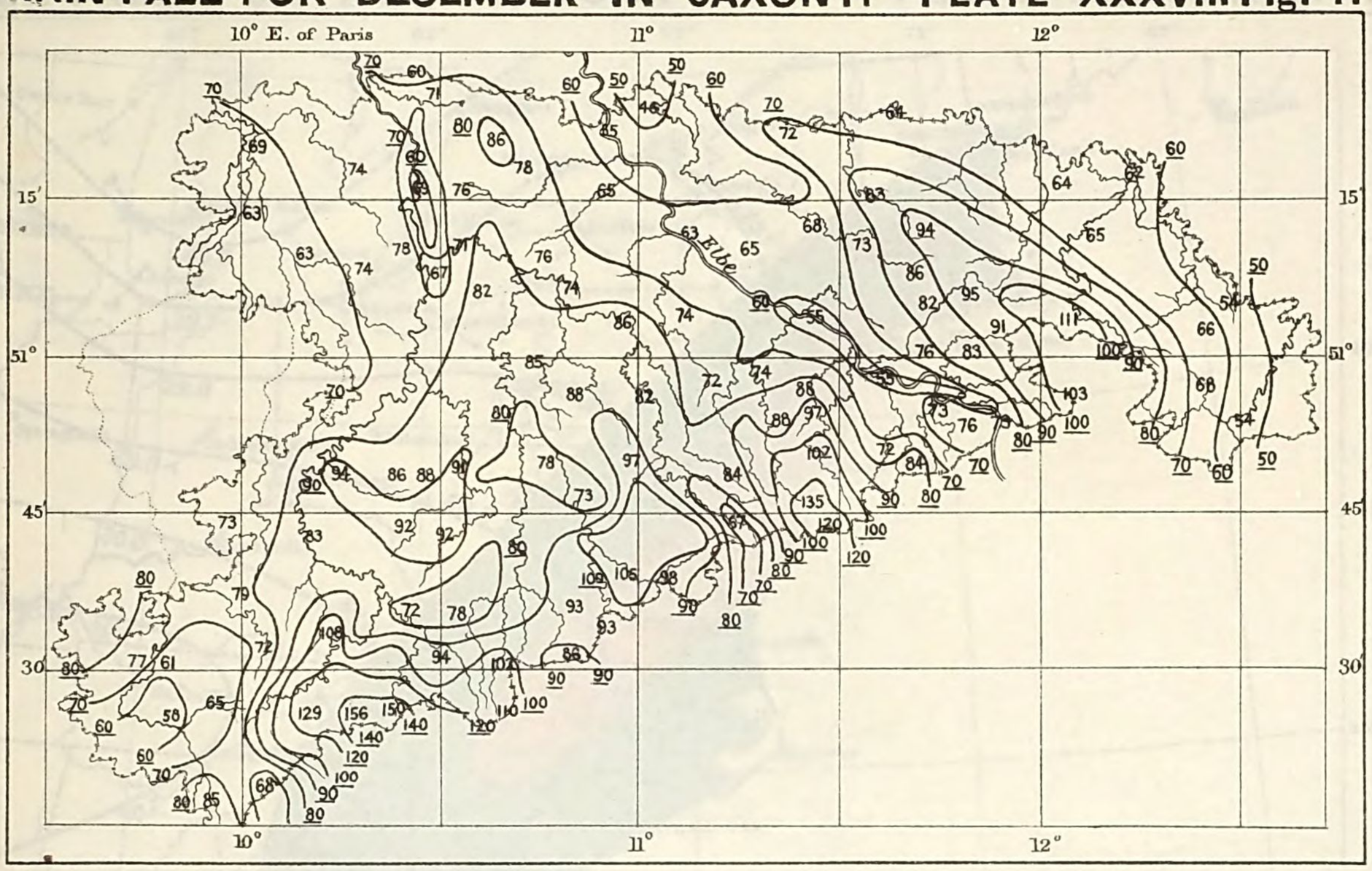


RAIN-FALL FOR AUG. 8, 1874. 7.32 A. M. Fig. 2.

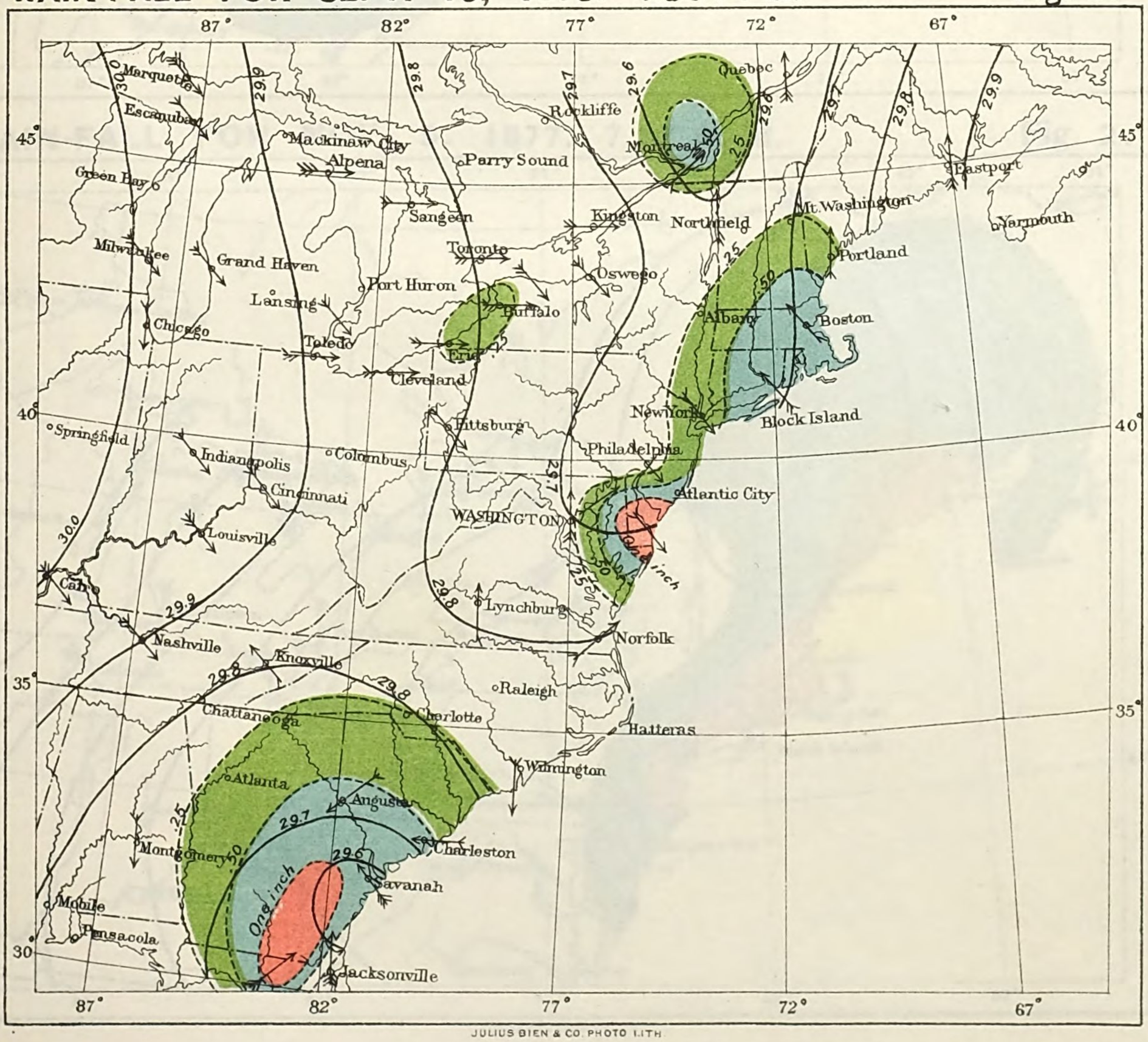


MEAN RELATIVE HUMIDITY PLATE XXXVI. Fig. 1.

RAIN-FALL FOR DECEMBER IN SAXONY. PLATE XXXVII. Fig. 1.



RAIN-FALL FOR SEPT. 19, 1873. 4.35 P. M. Fig. 2.



JULIUS BIEN & CO. PHOTO LITH.



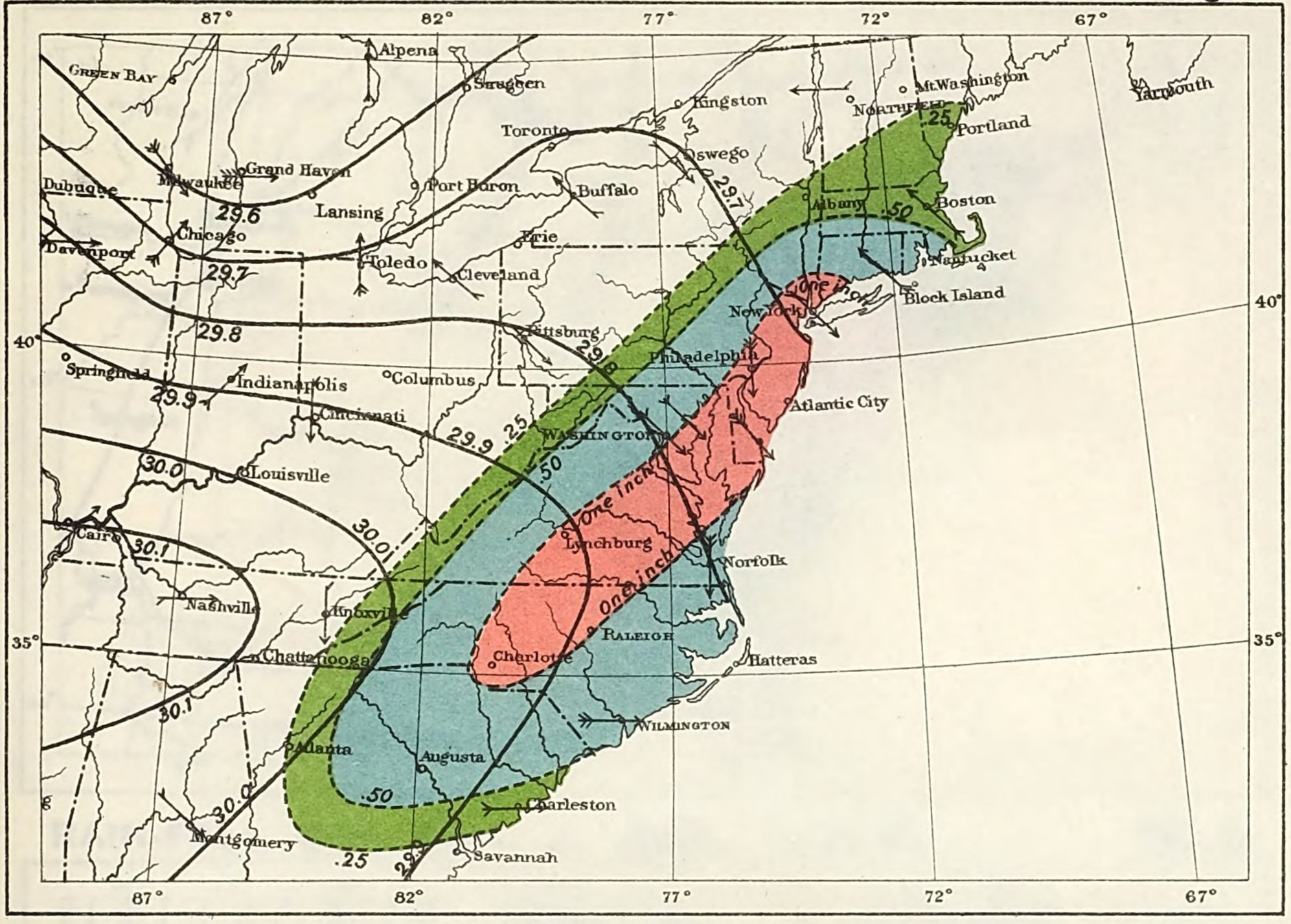
Fig. 3.

RAIN-FALL FOR SEPT. 18. 1873. 4.32 P. M.

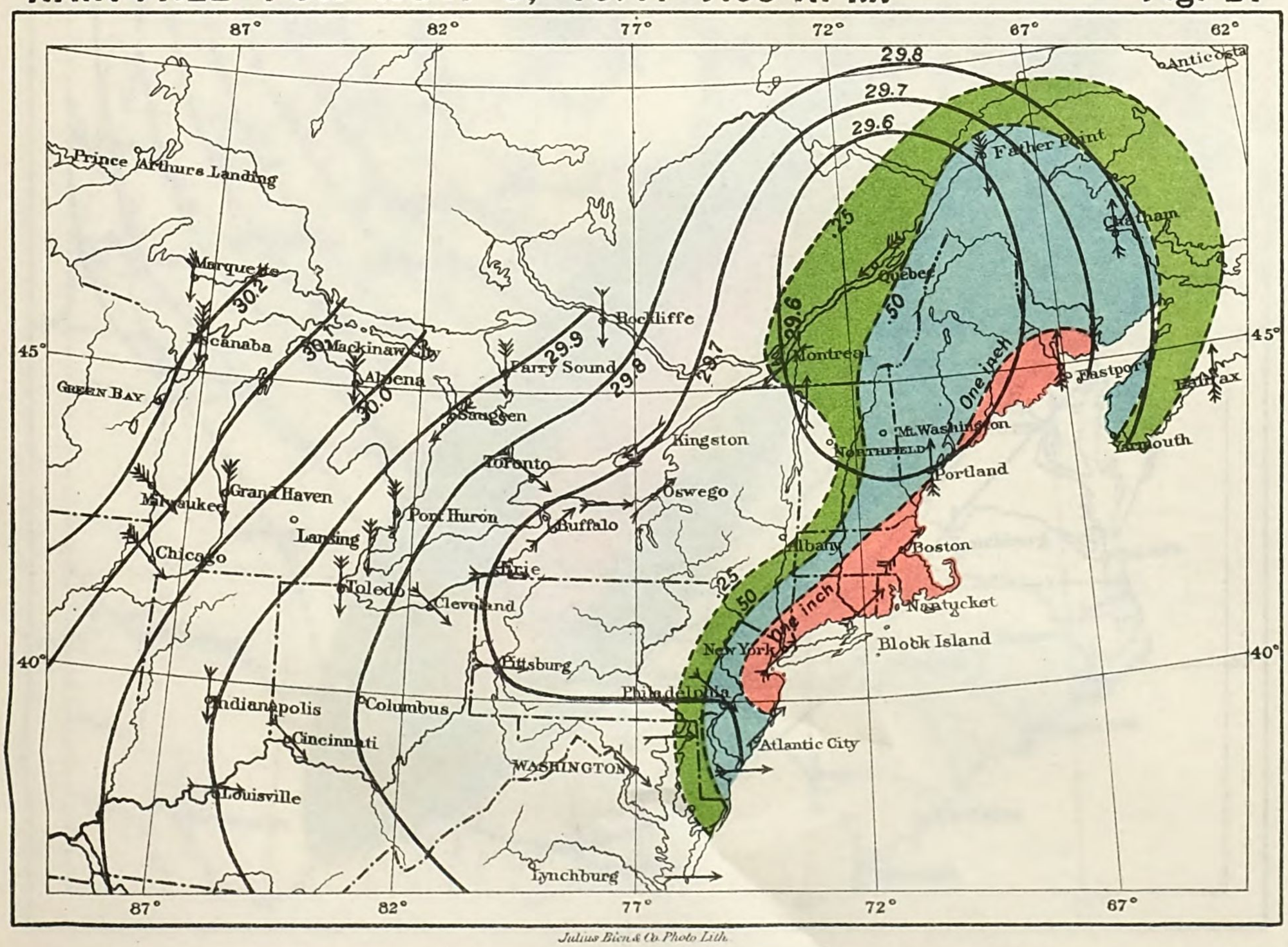
Fig. 4.

RAIN-FALL FOR DECEMBER IN SAXONY. PLATE XXXVII. FIG. 1.

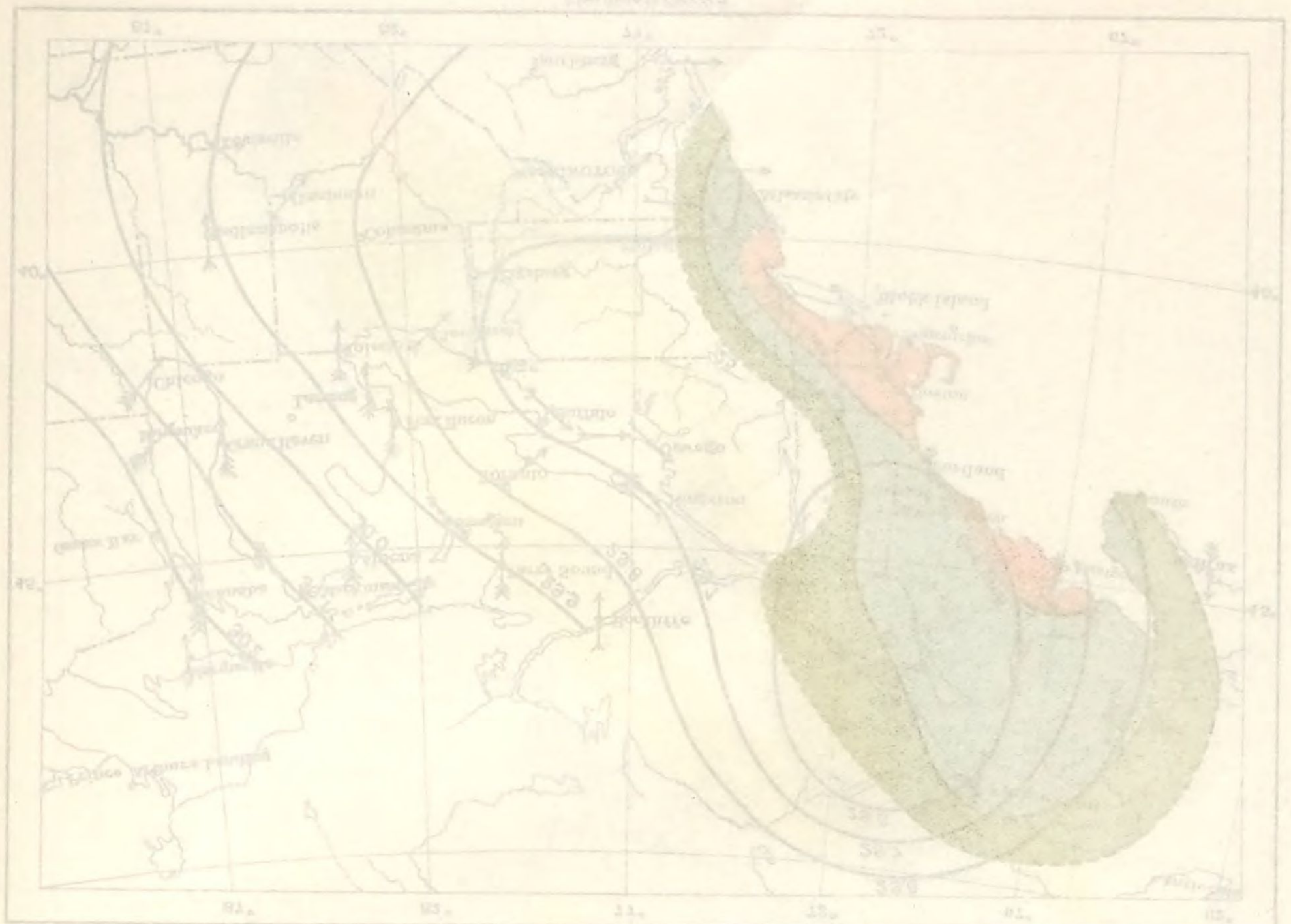
RAIN-FALL FOR NOV. 7, 1872. PLATE XXXVIII. Fig. 1.



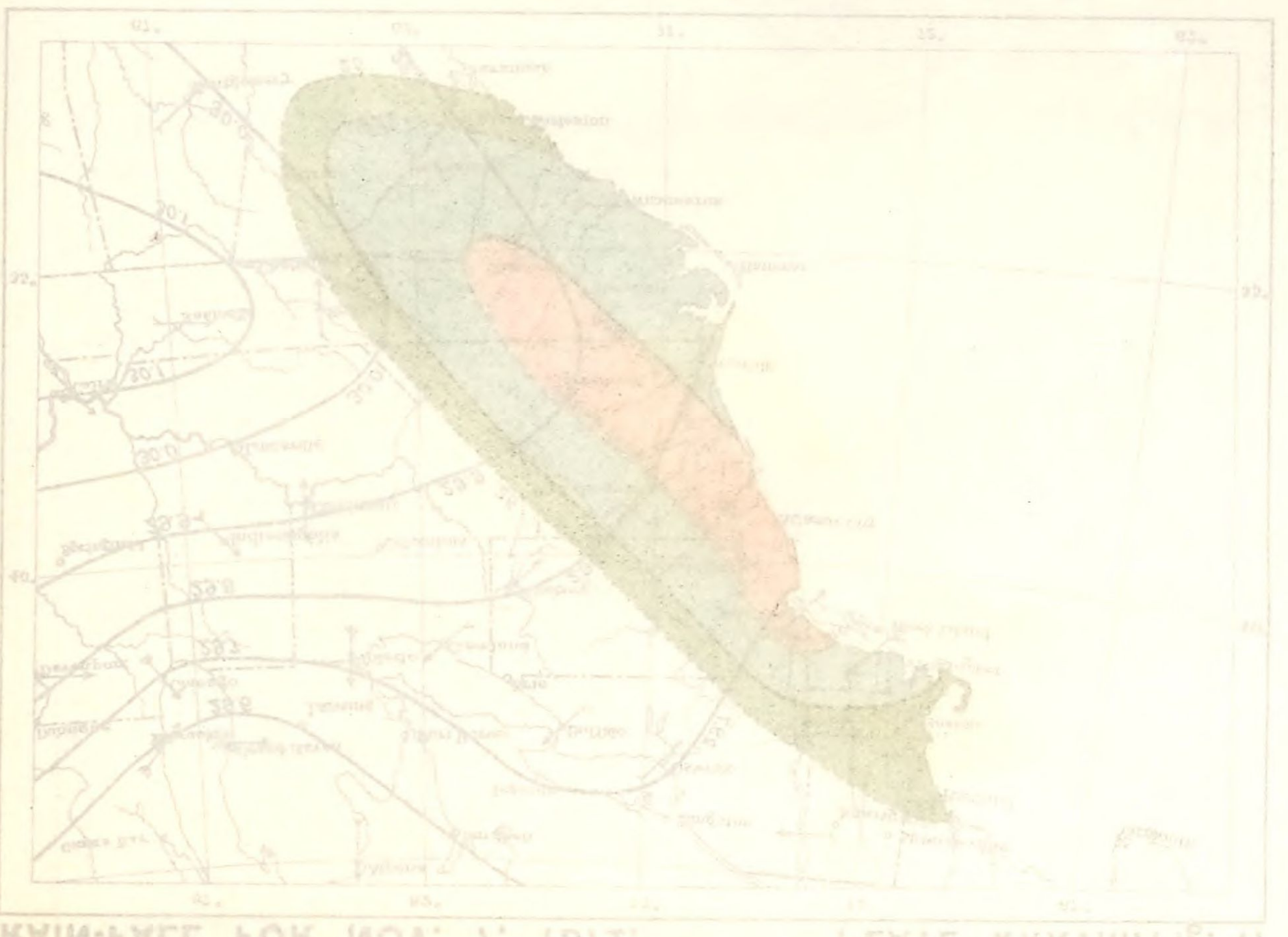
RAIN-FALL FOR NOV. 9, 1877. 7.35 A. M. Fig. 2.



Julius Bien & Co. Photo Lith.

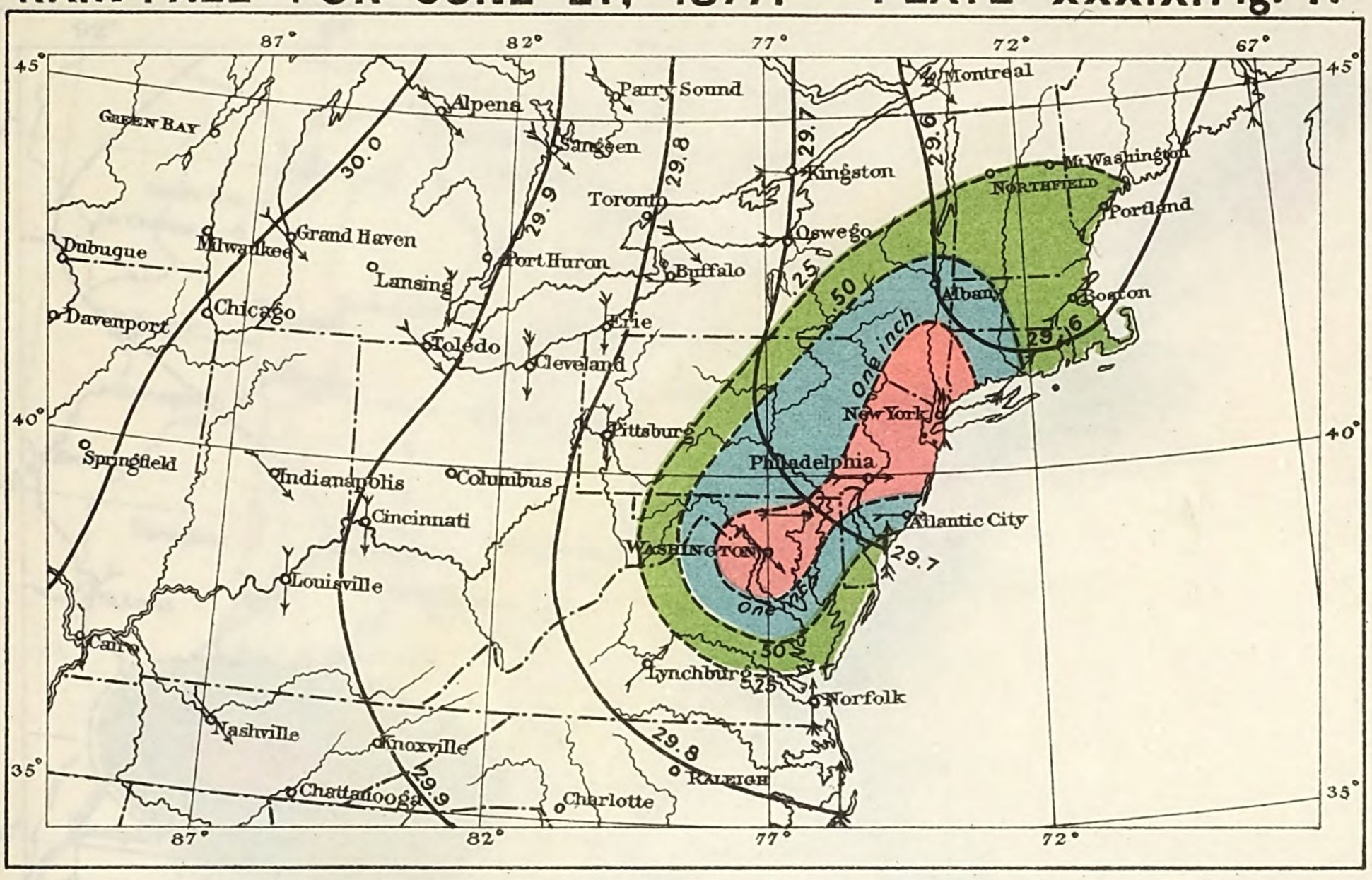


RAIN-FALL FOR NOV. 7, 1873. PLATE XXXVIII. FIG. 1.

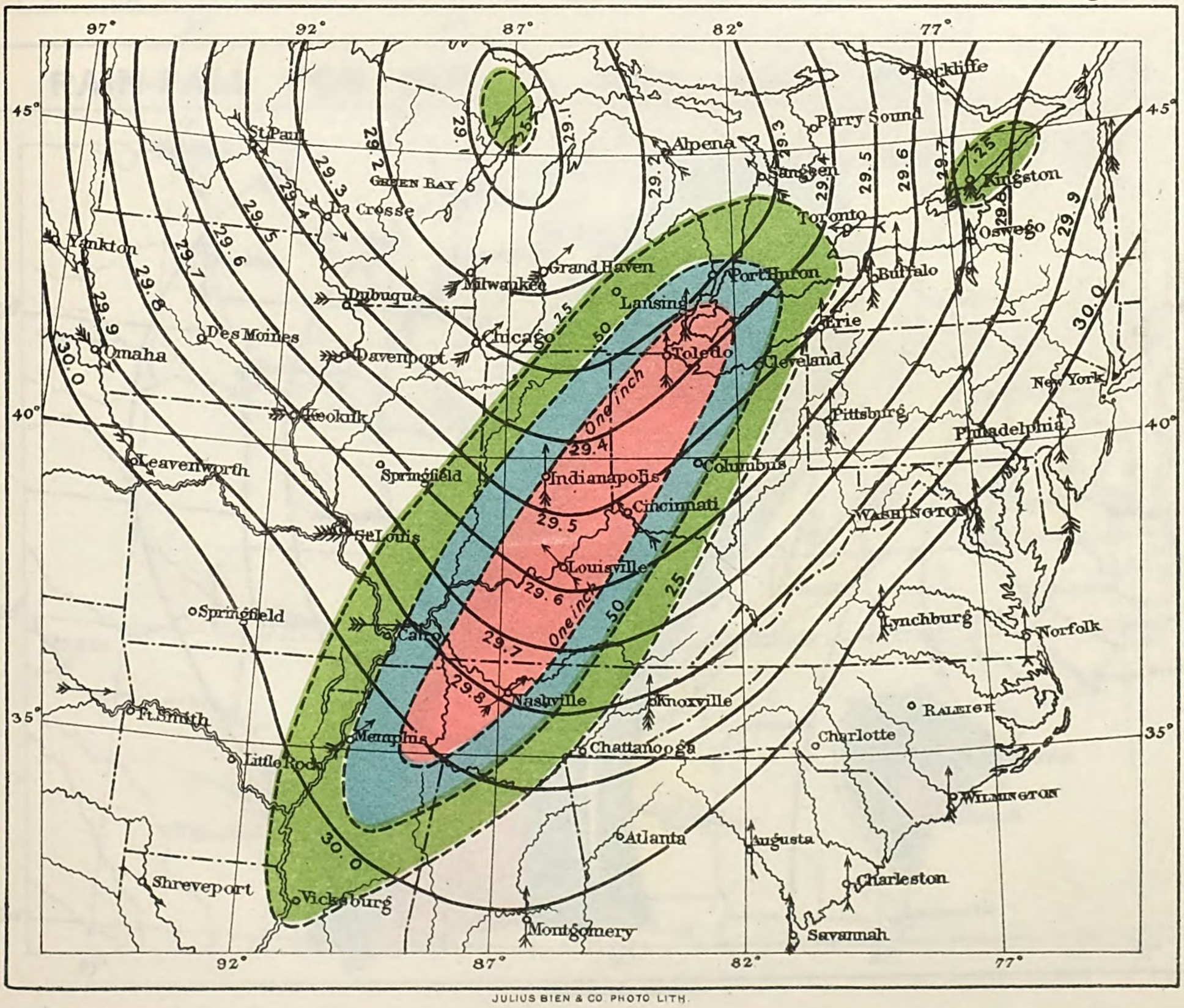


RAIN-FALL FOR NOV. 7, 1873. PLATE XXXVIII. FIG. 2.

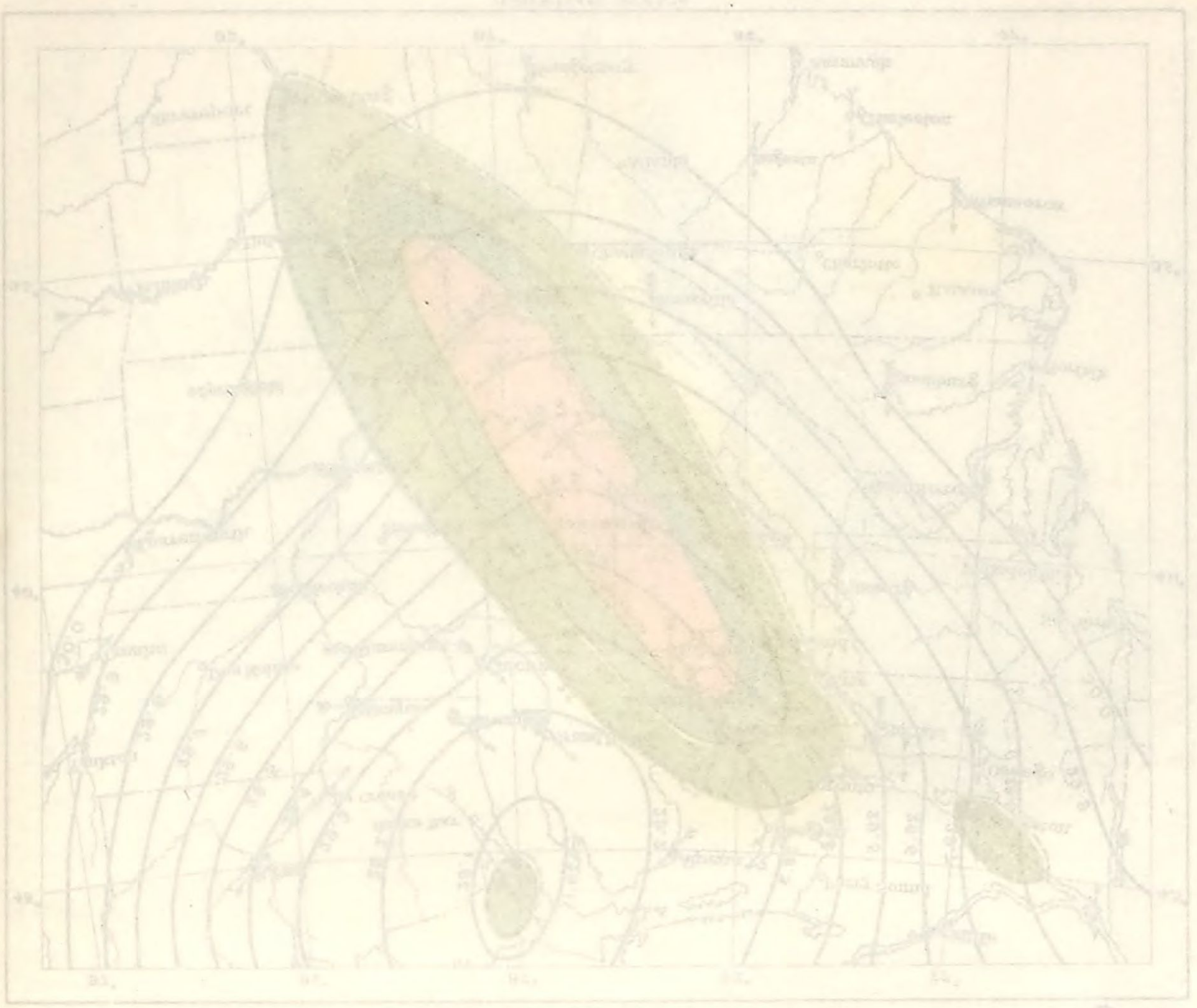
RAIN-FALL FOR JUNE 21, 1877. PLATE XXXIX. Fig. 1.



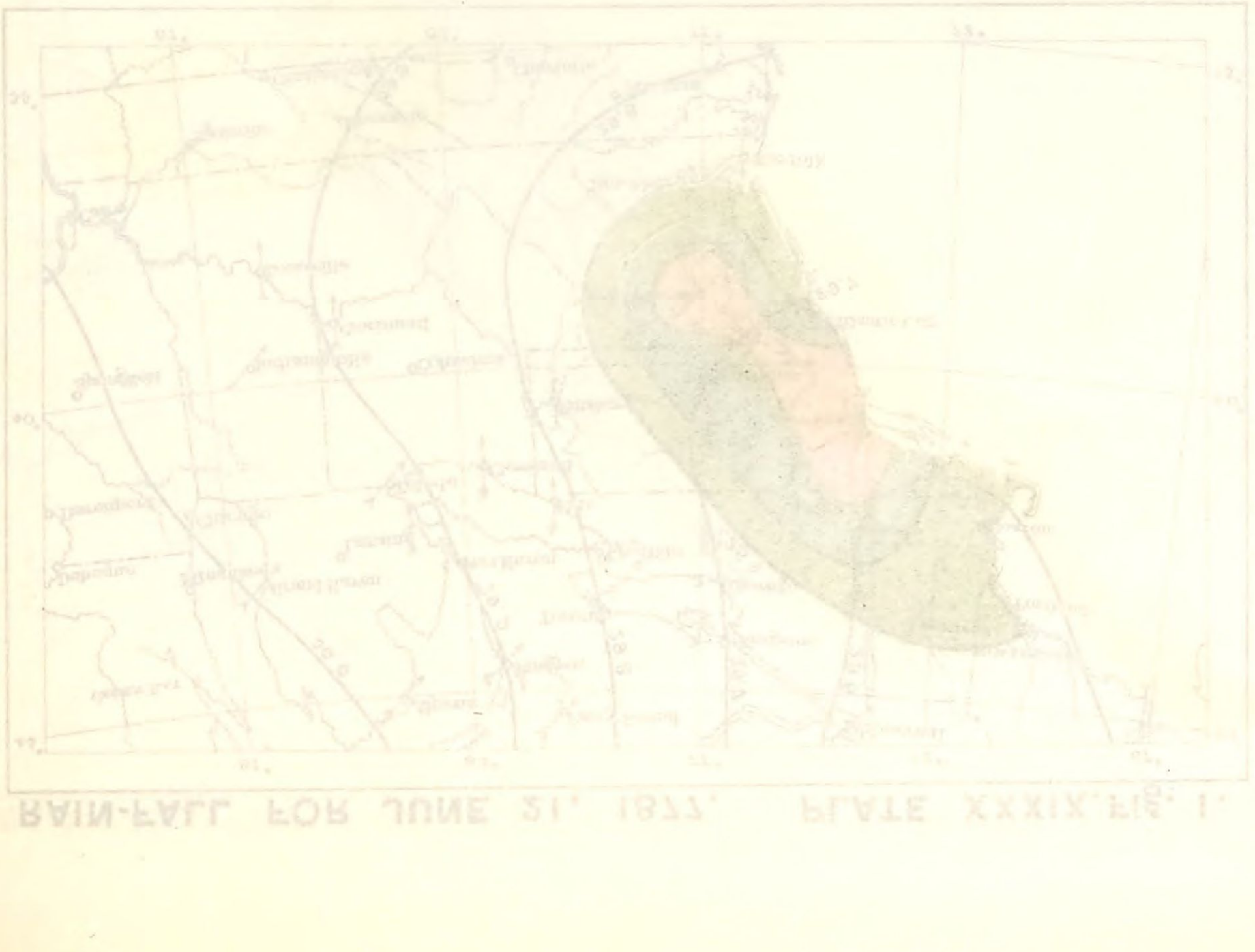
RAIN-FALL FOR DEC. 3, 1873. 11 P. M. Fig. 2.



JULIUS BIEN & CO. PHOTO LITH.

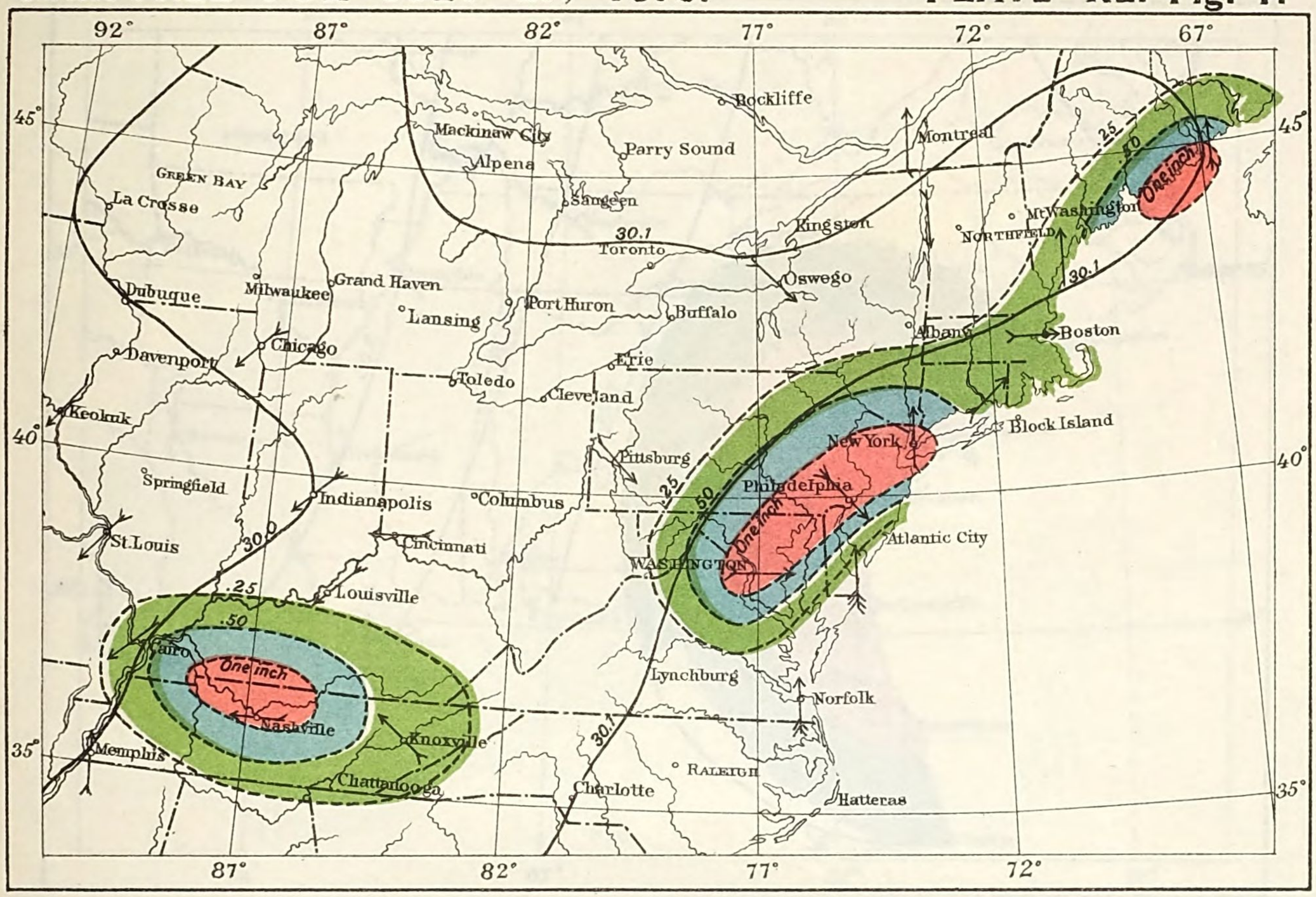


RAIN-FALL FOR DEC. 3, 1873. 11 P. M. FIG. 5.

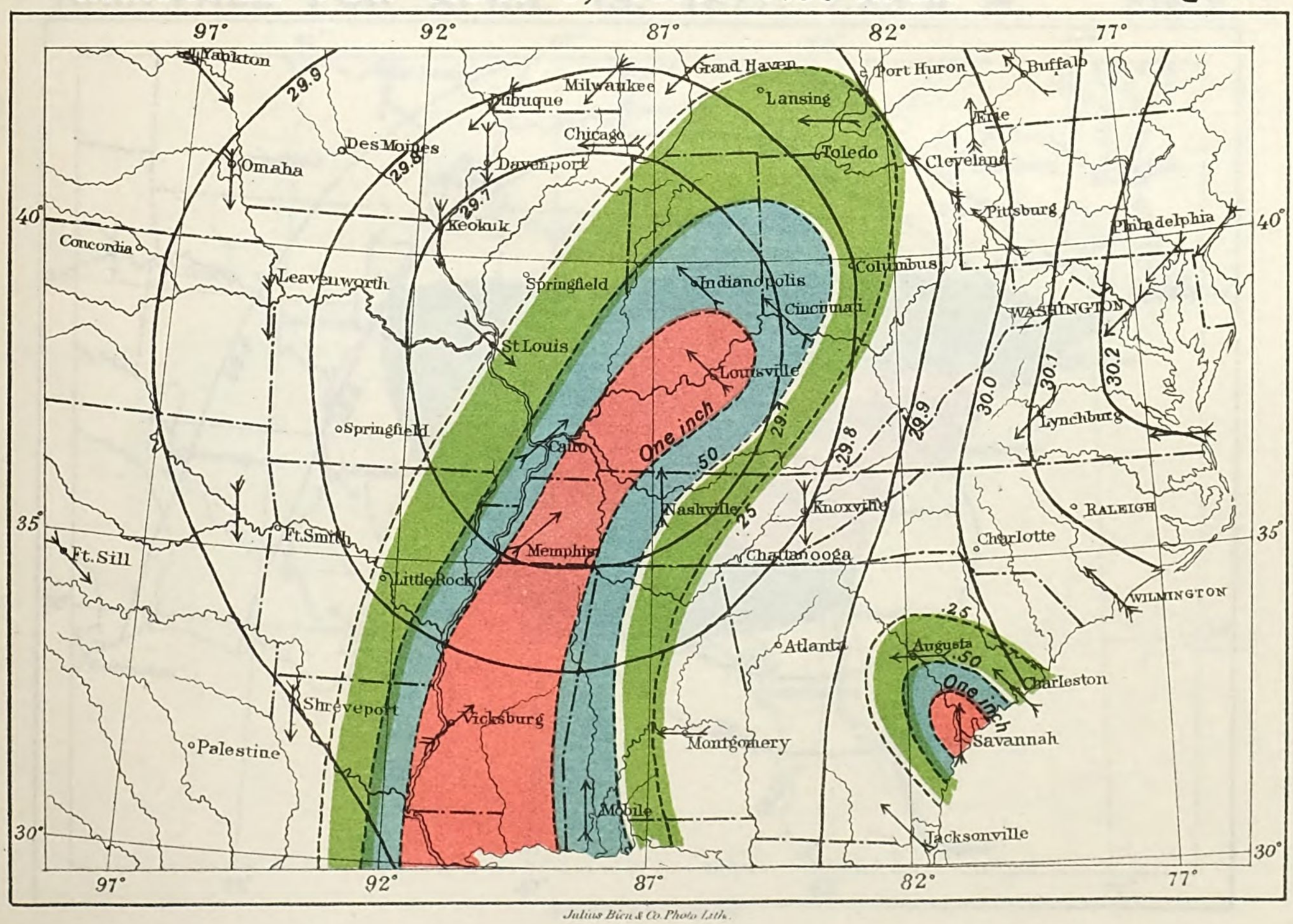


RAIN-FALL FOR JUNE 21, 1873. PLATE XXXIX. FIG. 1.

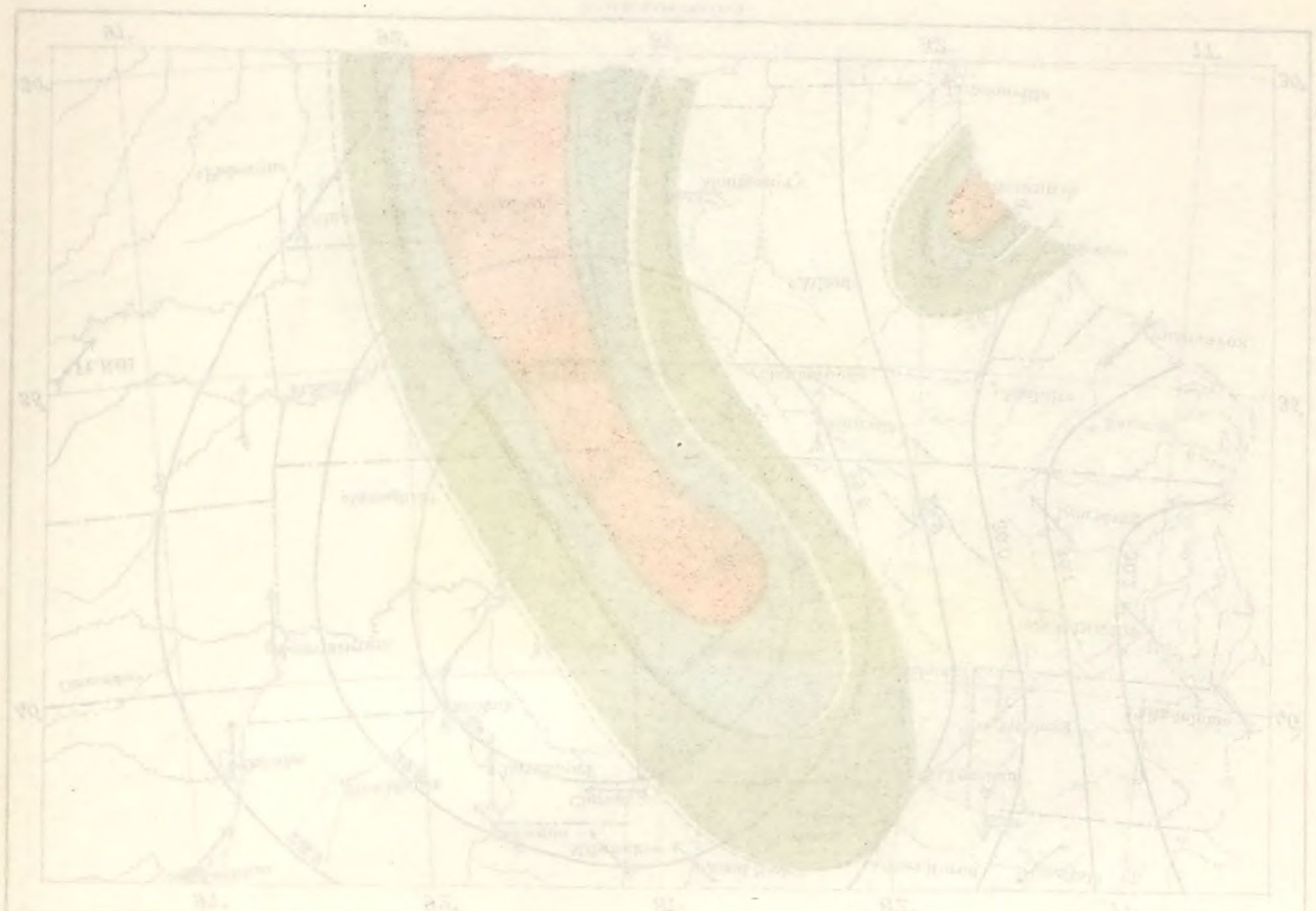
RAIN-FALL FOR JULY 27, 1873. PLATE XL. Fig. 1.



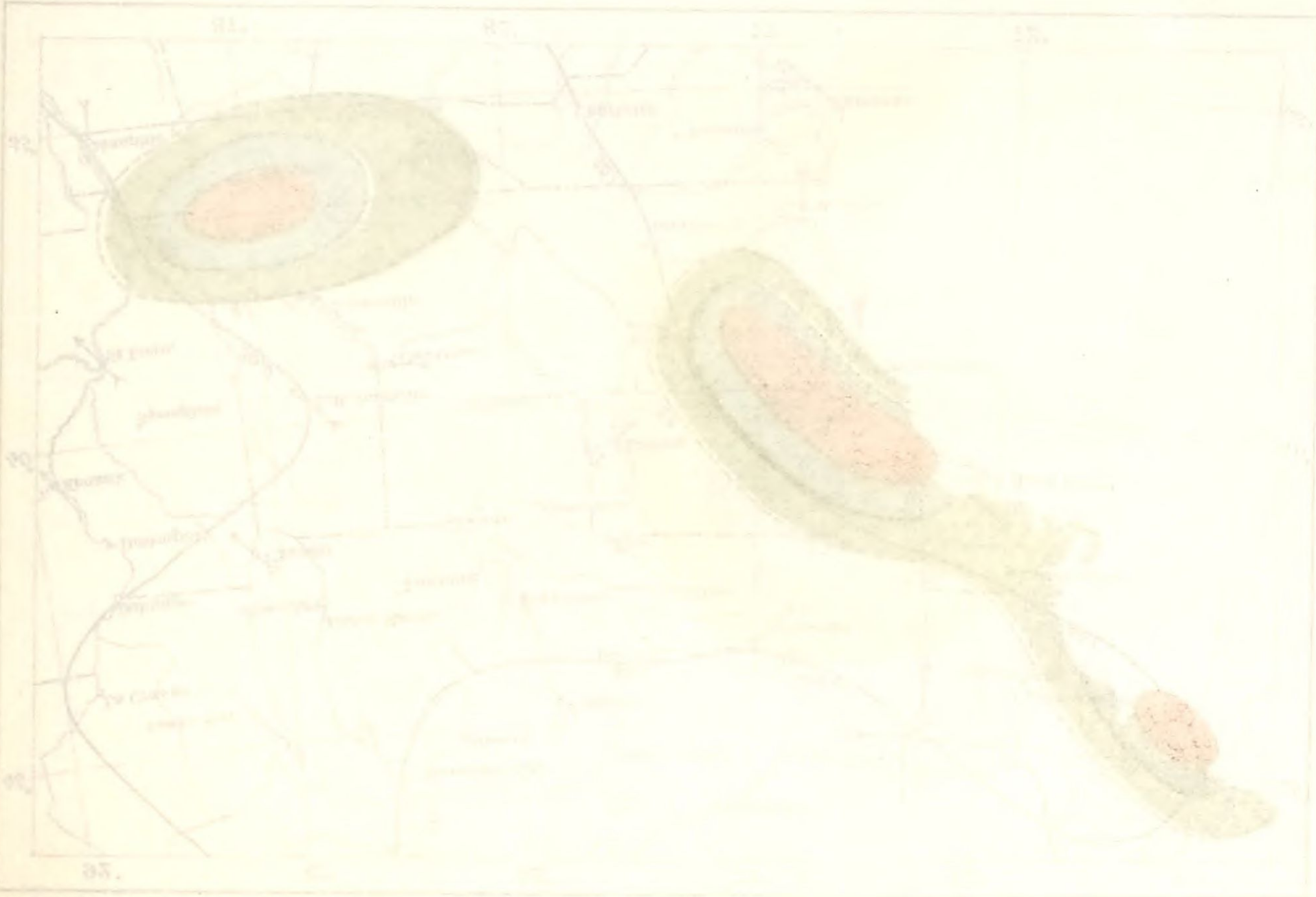
RAIN-FALL FOR NOV. 8, 1877. 7.35 A. M. Fig. 2.



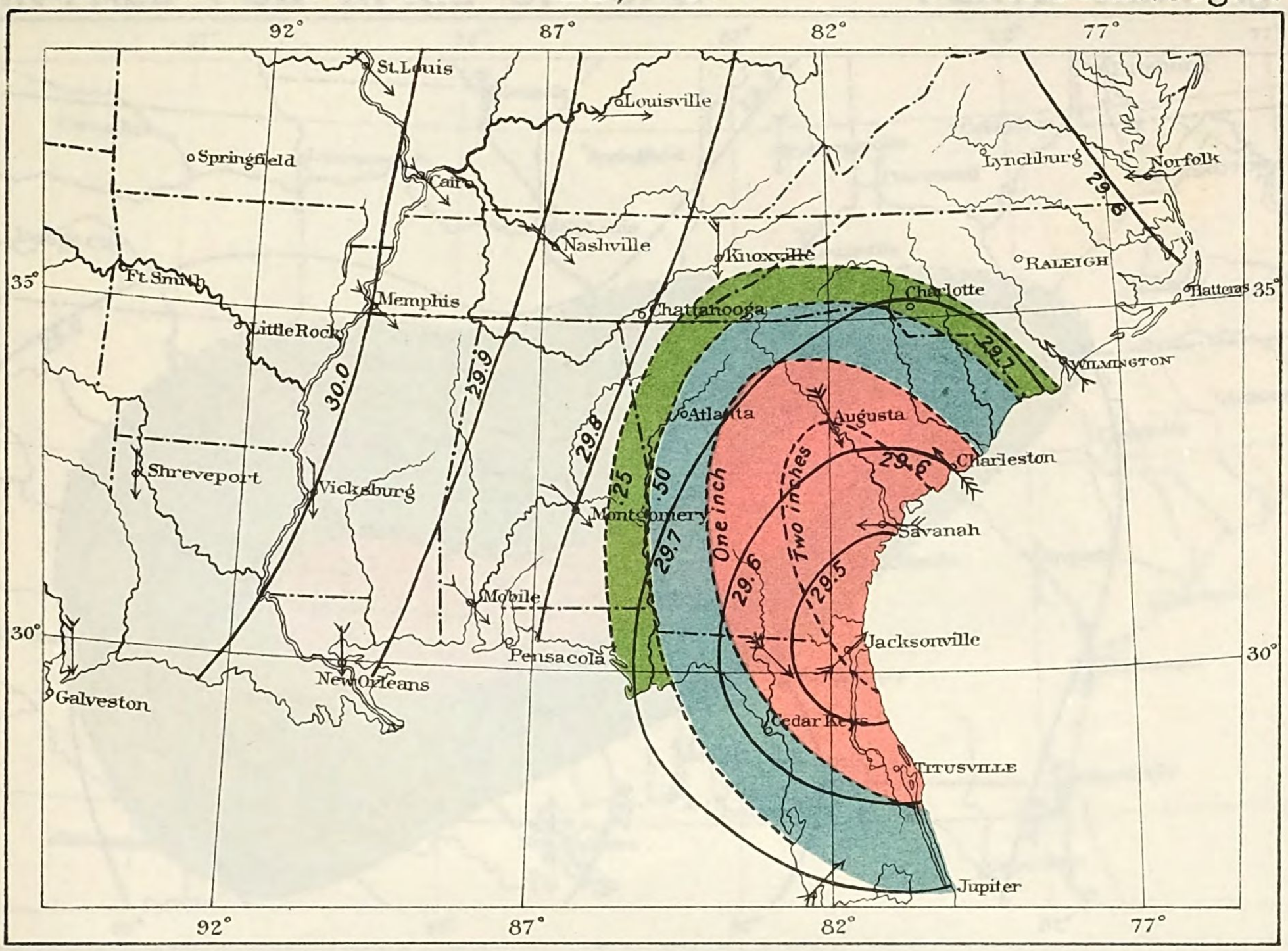
Julius Bien & Co. Photo Lith.



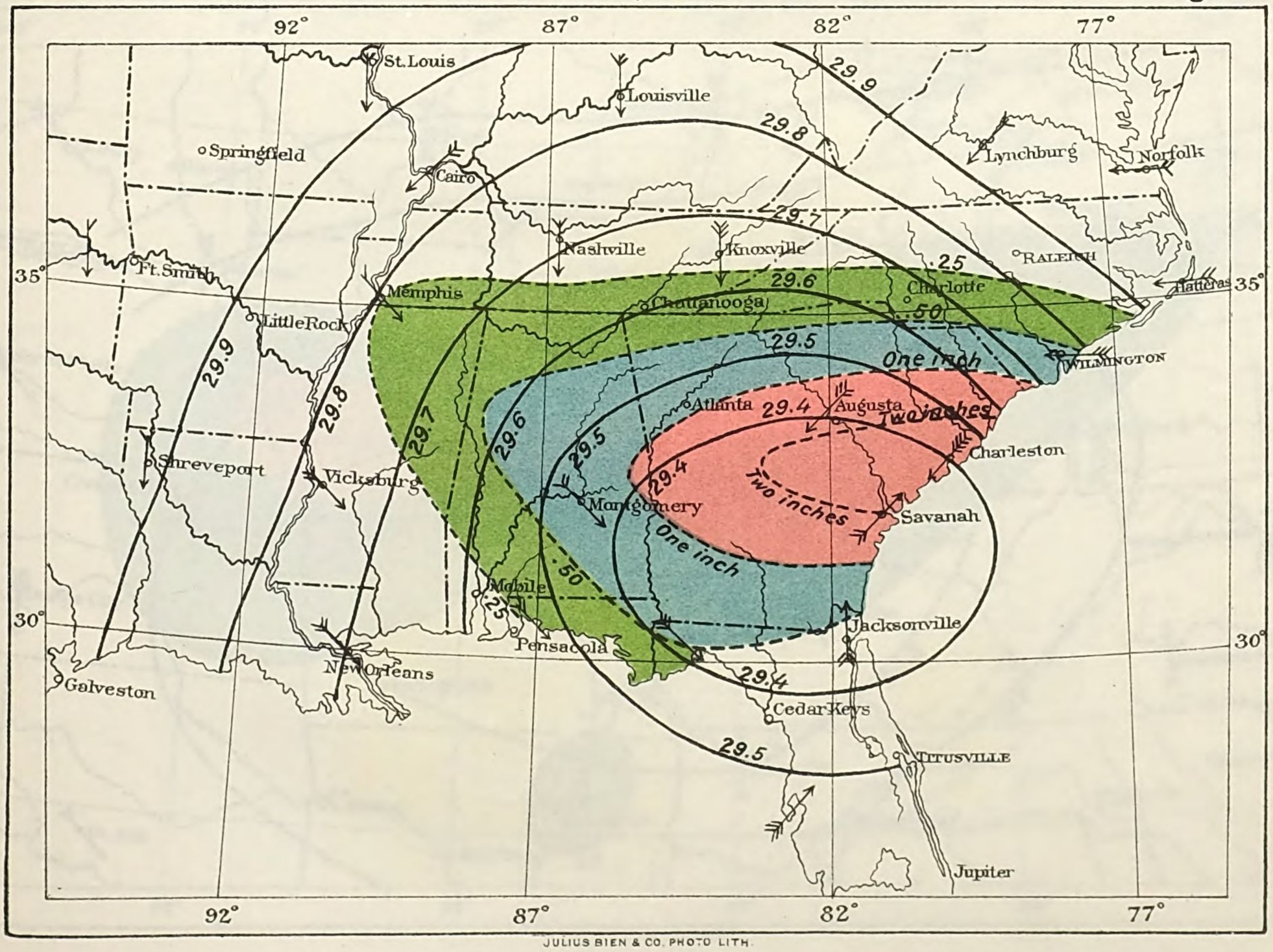
RAIN-FALL FOR NOV. 8, 1833, 7.32 A. M. FIG. 5.



RAIN-FALL FOR SEPT. 28, 1874 PLATE XLI. Fig. 1.



RAIN-FALL FOR APRIL 13, 1877. 7.35 A. M. Fig. 2.

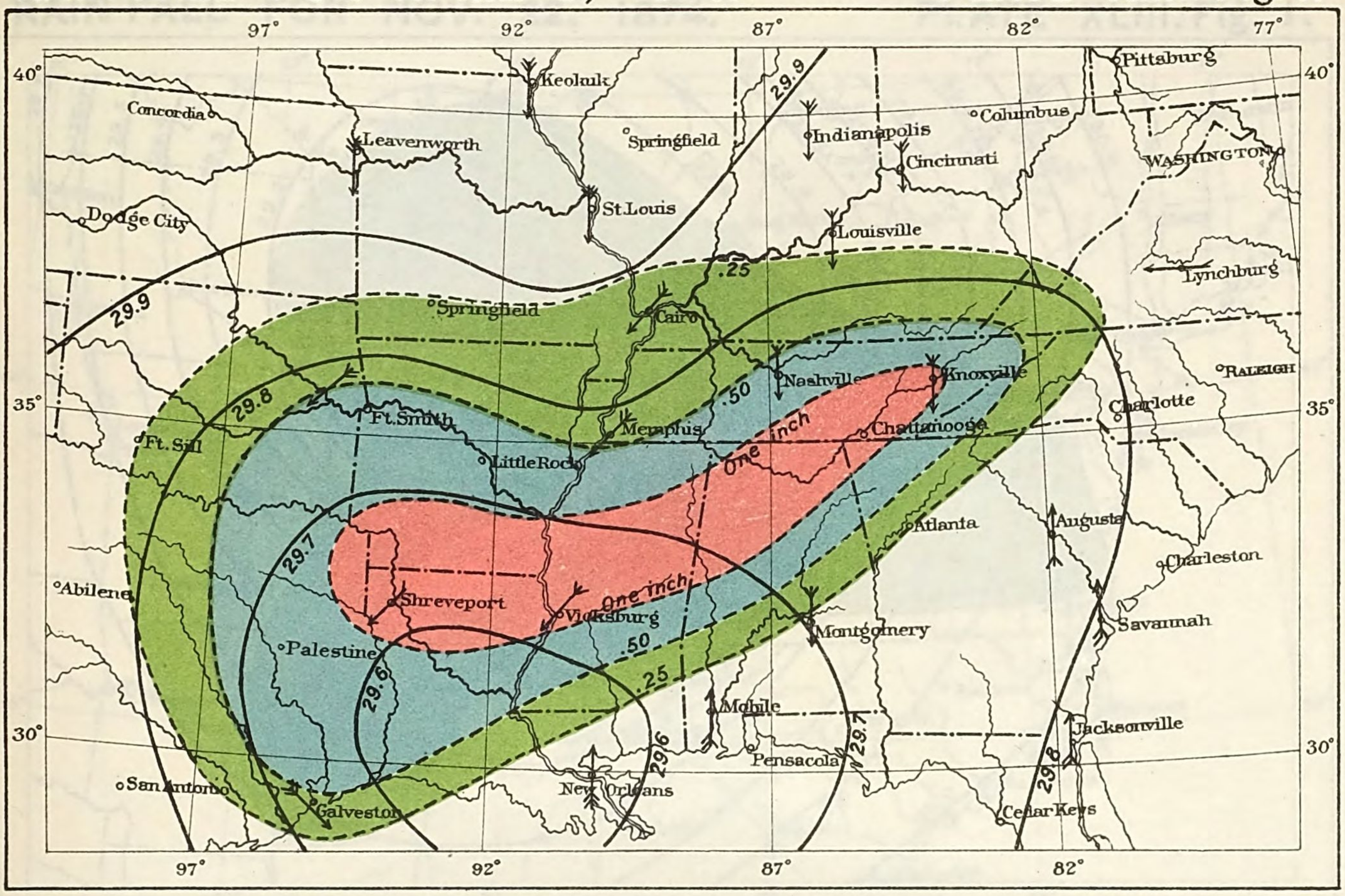


JULIUS BIEN & CO. PHOTO LITH.

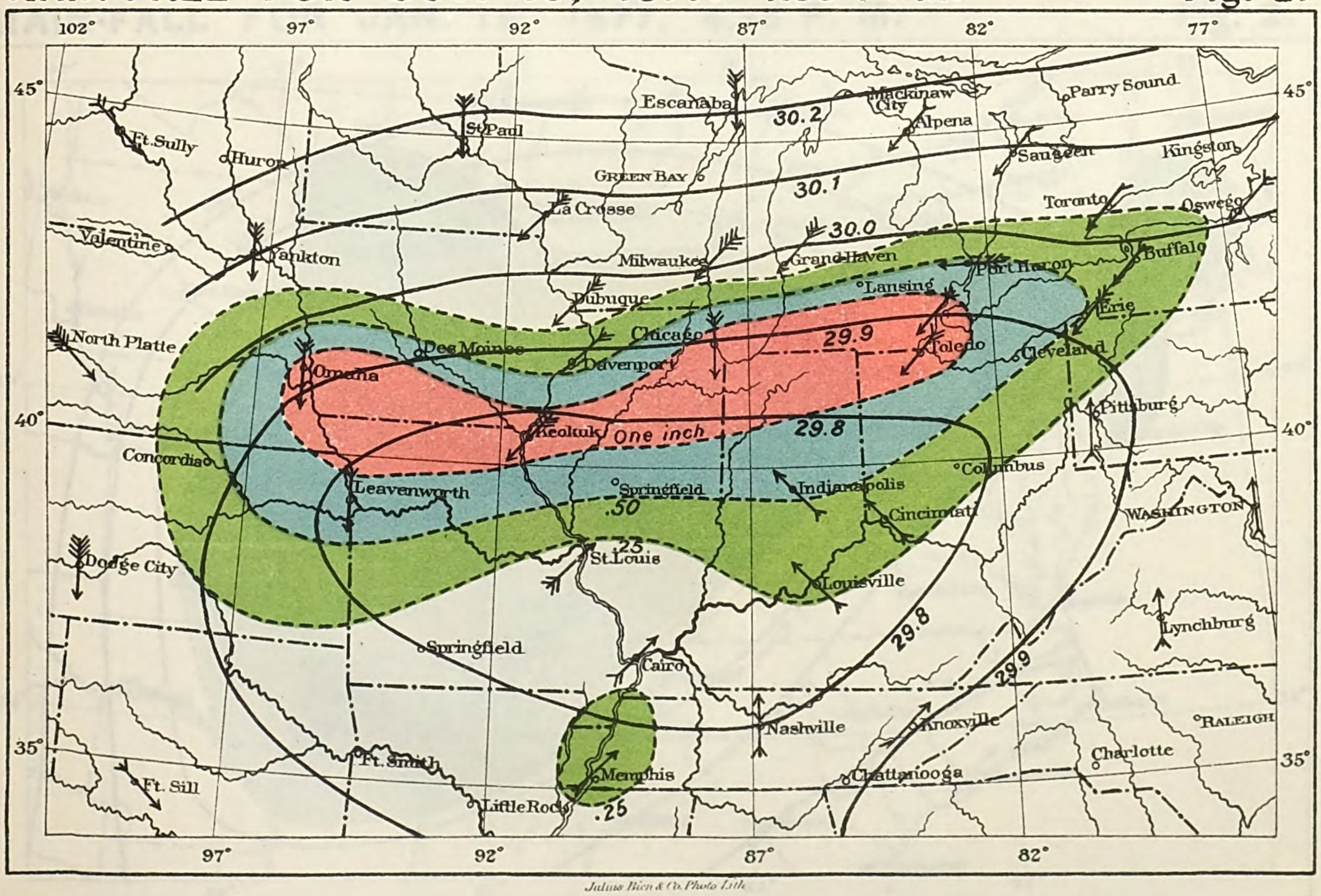
RAIN-FALL FOR SEPT. 28, 1874. PLATE XLI. Fig. 1.

RAIN-FALL FOR APRIL 13, 1872. 2.35 A.M. Fig. 2

RAIN-FALL FOR APRIL 8, 1874. PLATE XLII. Fig. 1.



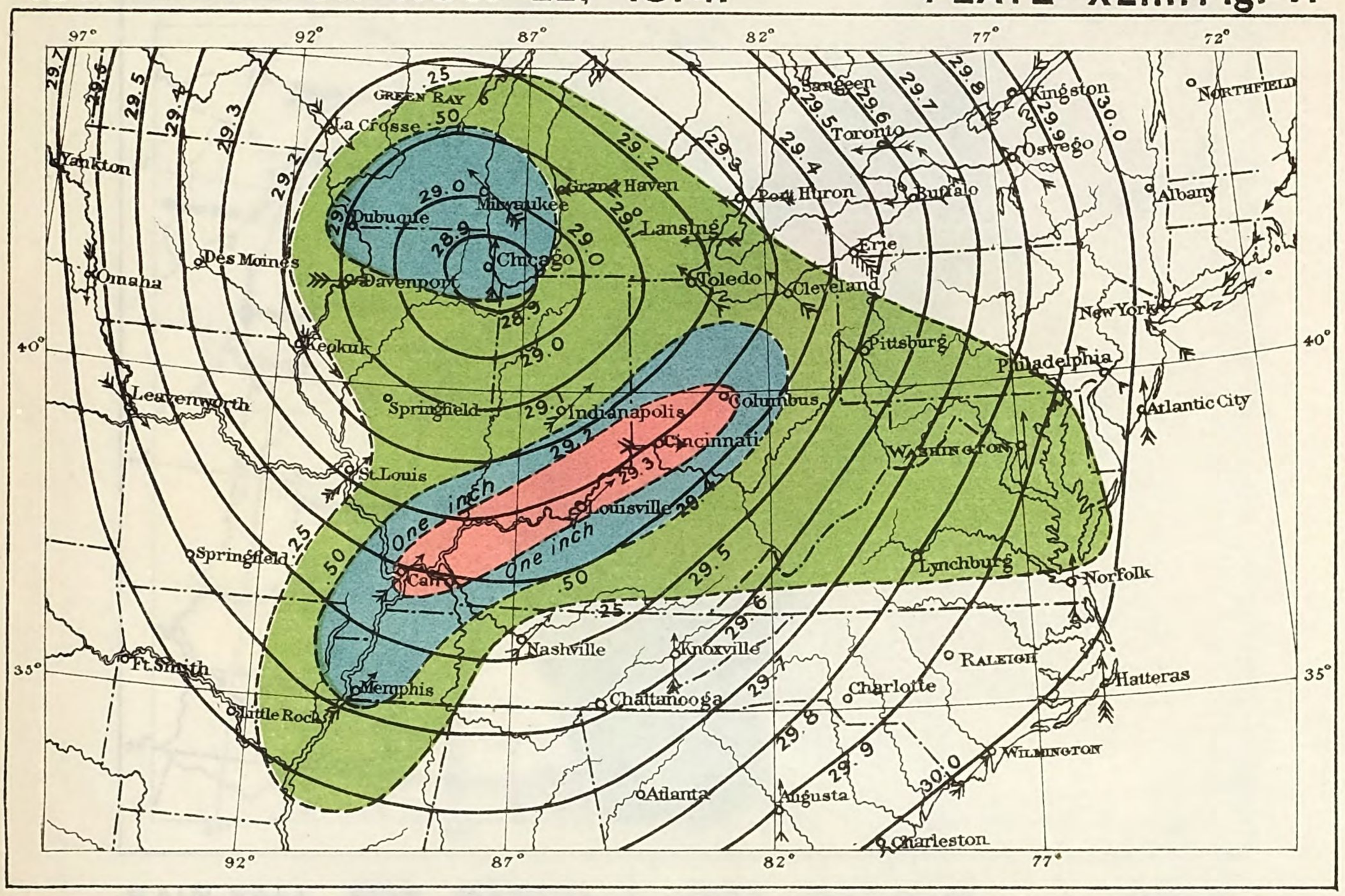
RAIN-FALL FOR OCT. 19, 1877. 4.35 P. M. Fig. 2.



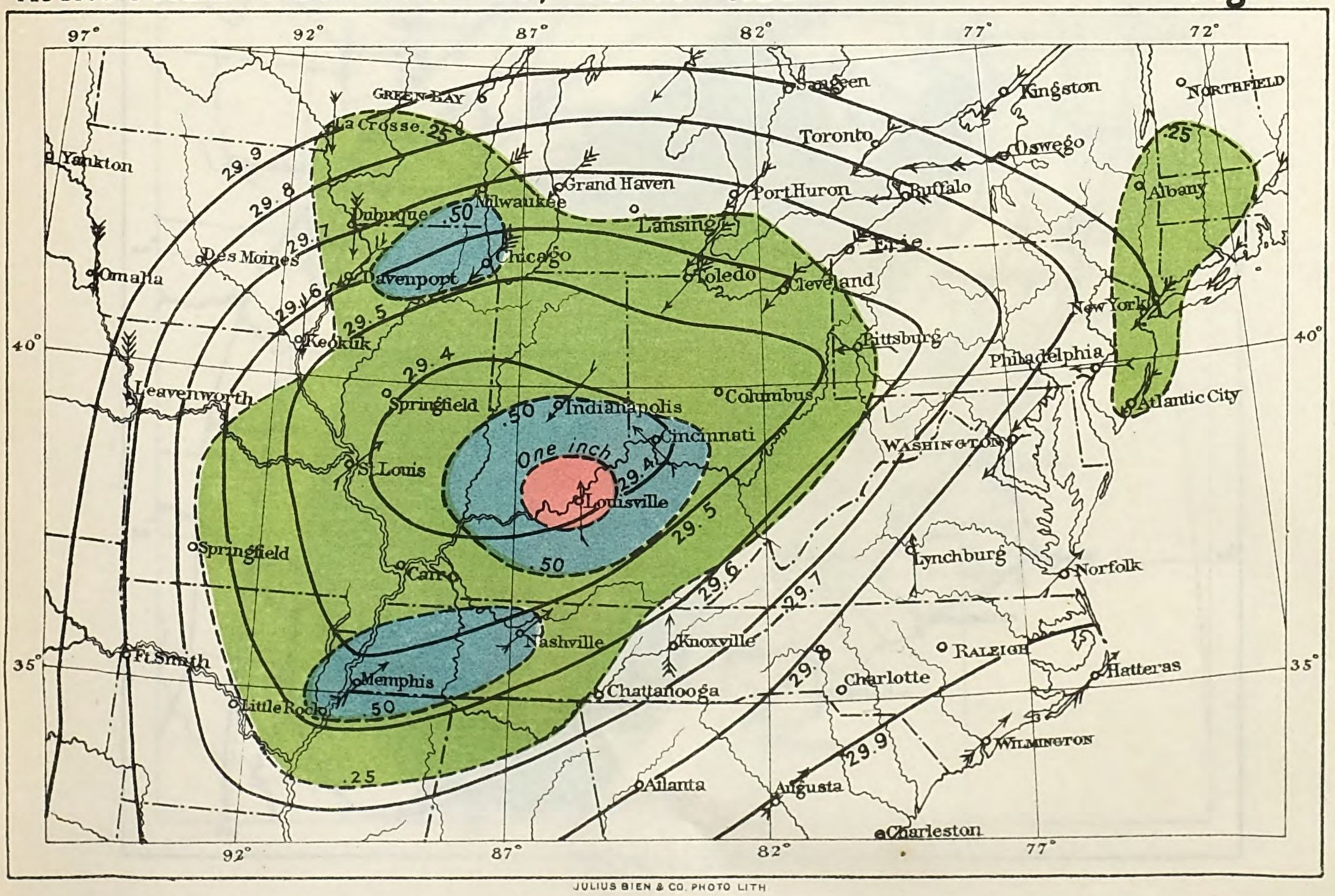
Julius Bien & Co. Photo Lith.

RAIN-FALL FOR APRIL 8, 1874. PLATE XLII. Fig. 1.

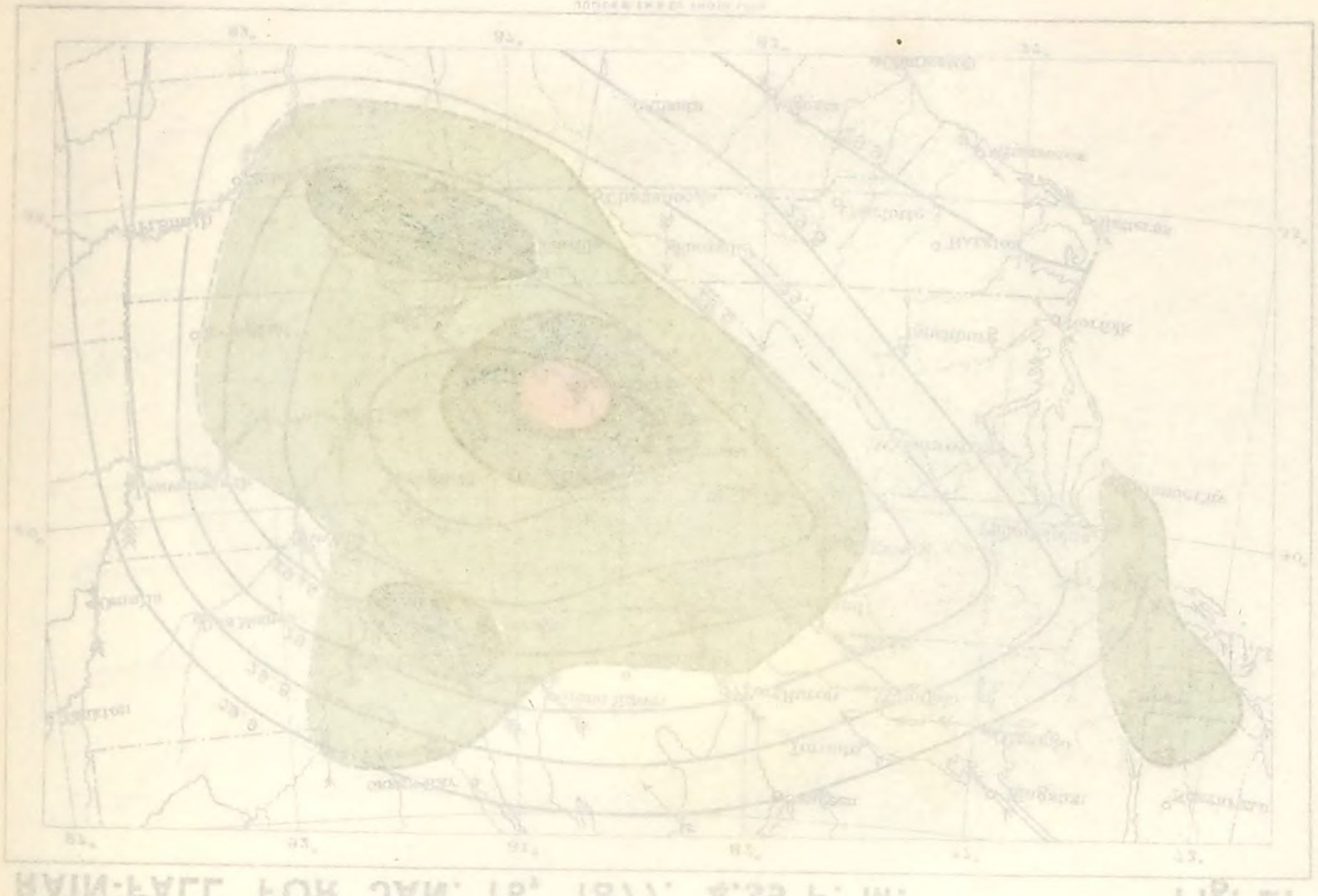
RAIN-FALL FOR NOV. 22, 1874. PLATE XLIII. Fig. 1.



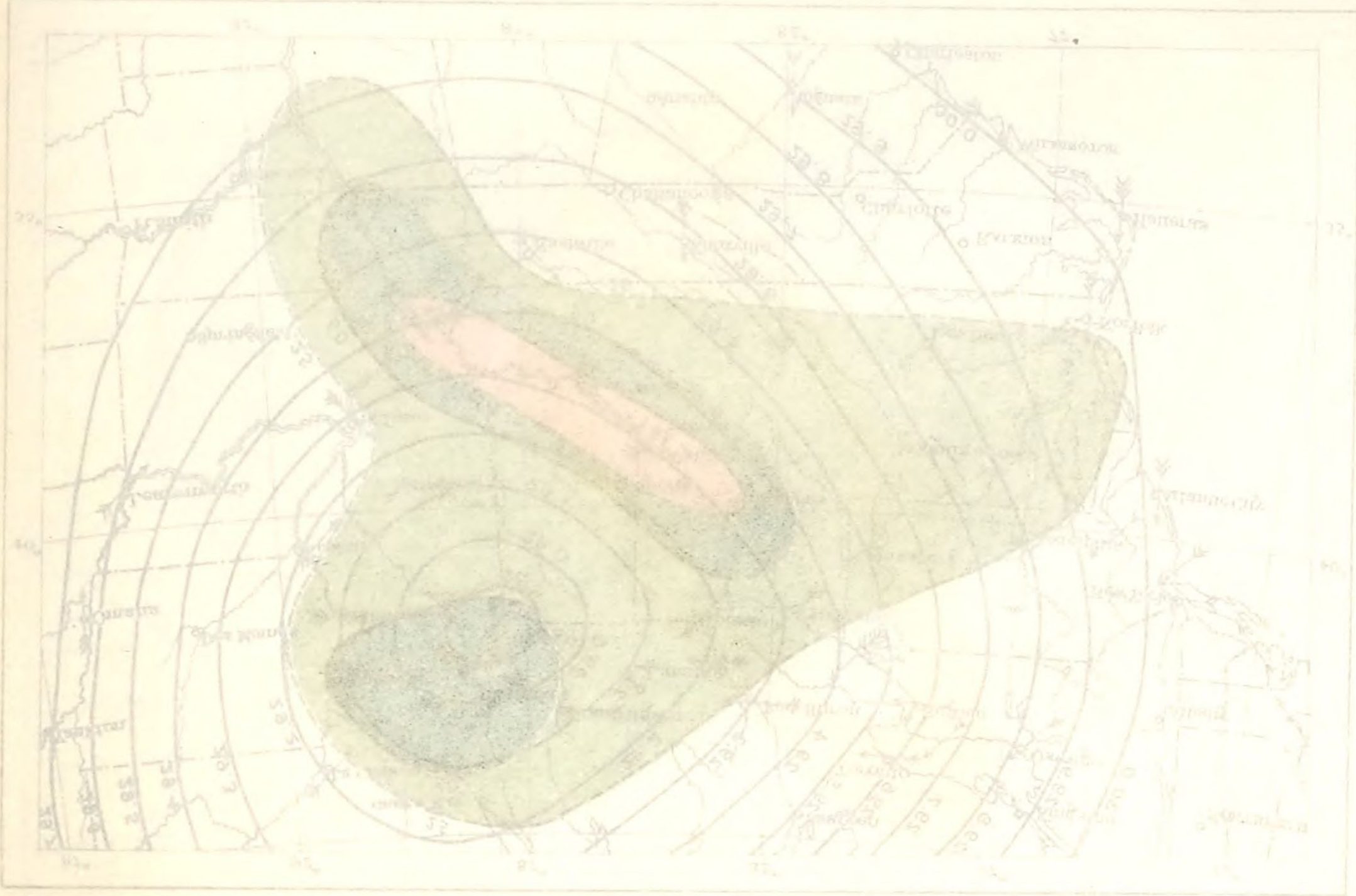
RAIN-FALL FOR JAN. 15, 1877. 4.35 P. M. Fig. 2.



JULIUS BIEN & CO. PHOTO LITH

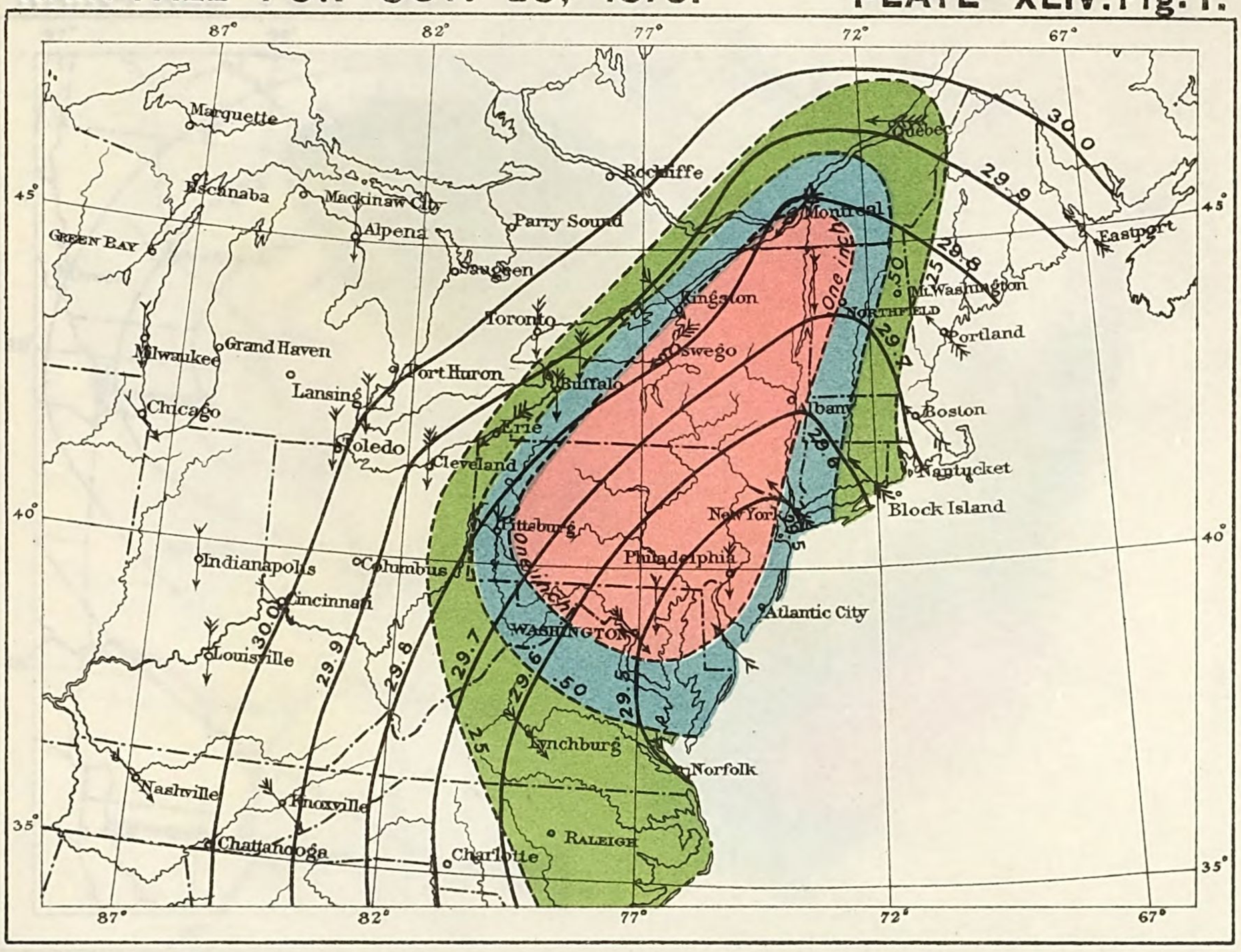


RAIN-CHART FOR JAN. 15, 1877. 4.35 P. M. FIG. 5.

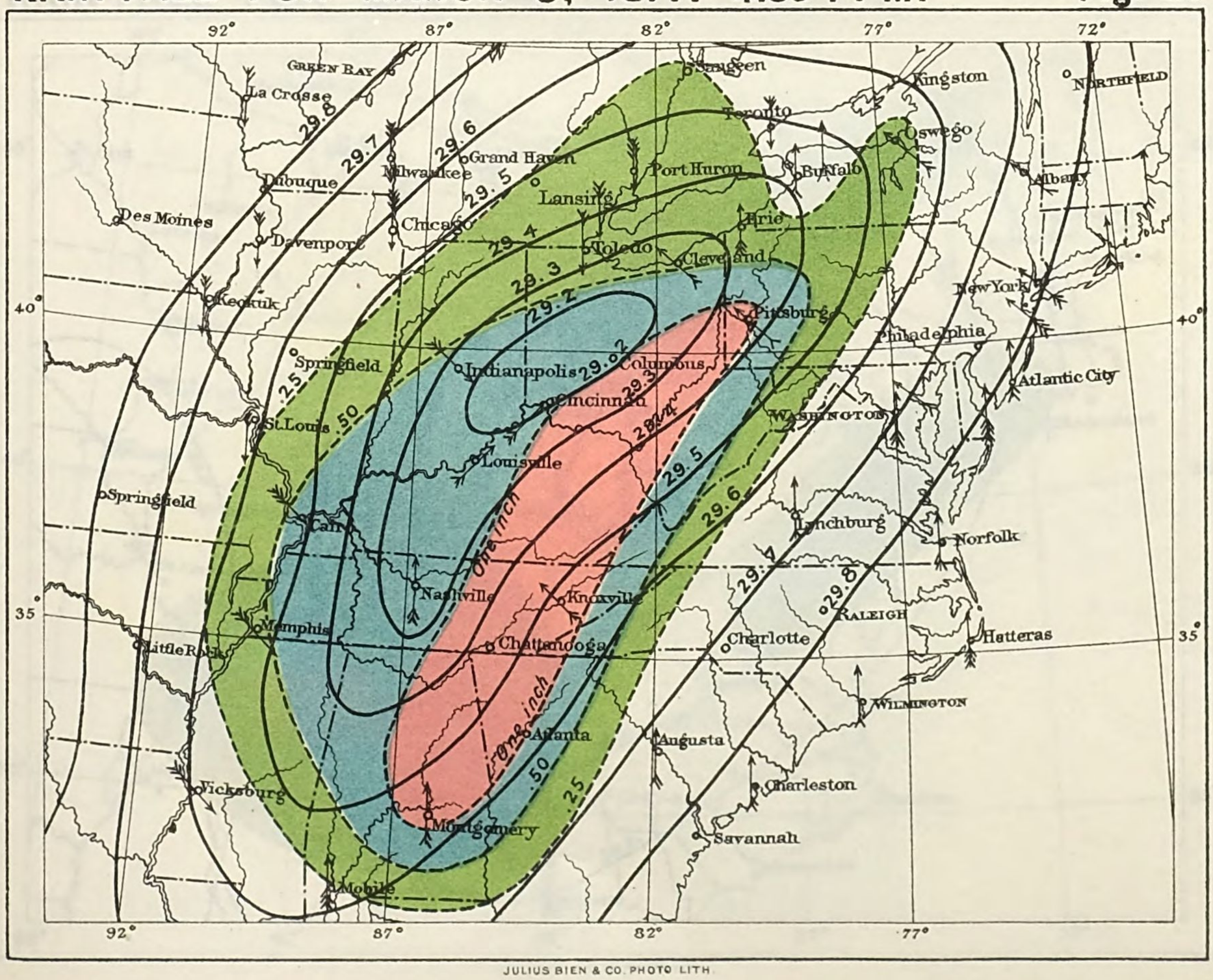


RAIN-CHART FOR NOV. 22, 1874. PLATE XLIII. FIG. 1.

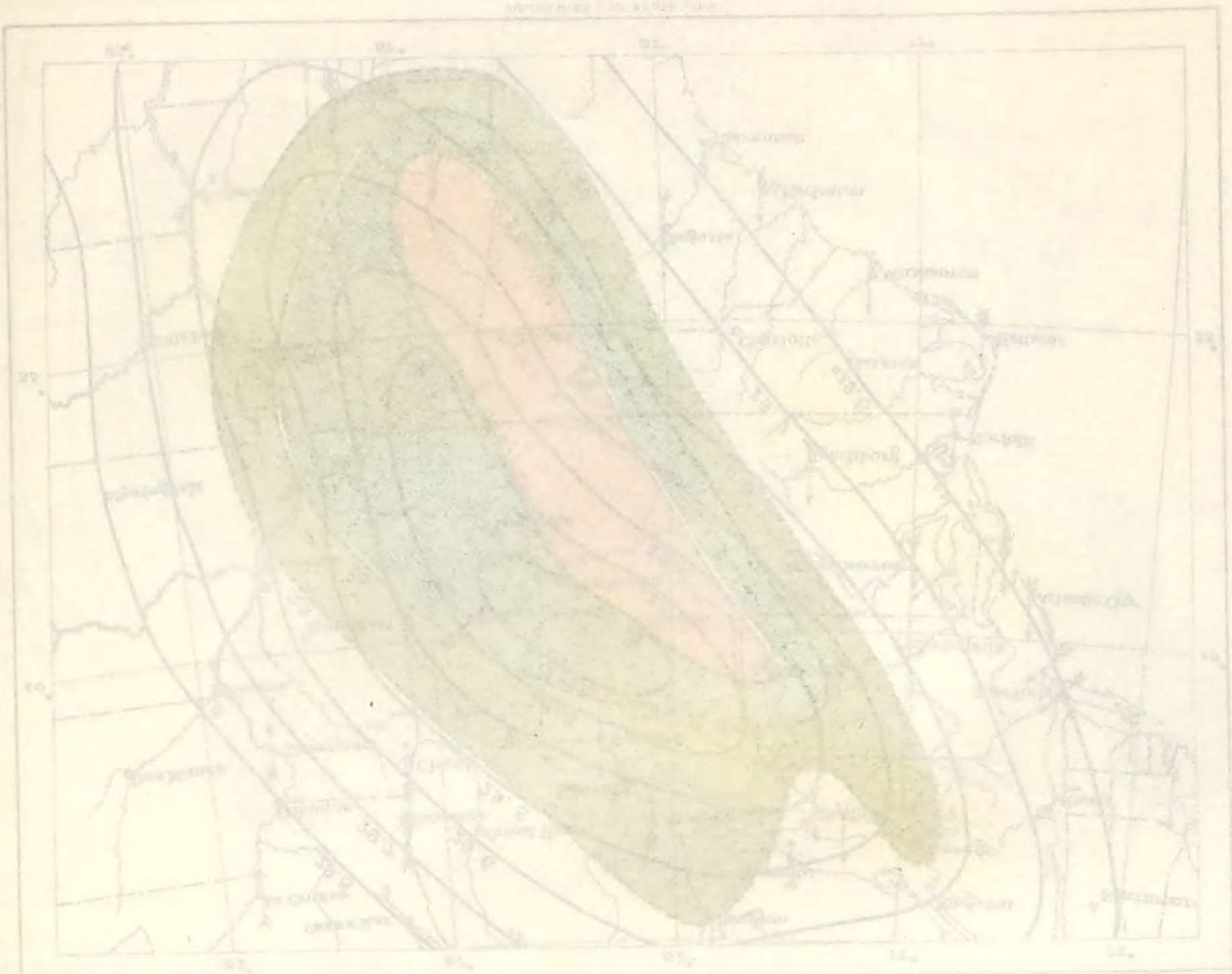
RAIN-FALL FOR OCT. 20, 1873. PLATE XLIV. Fig. 1.



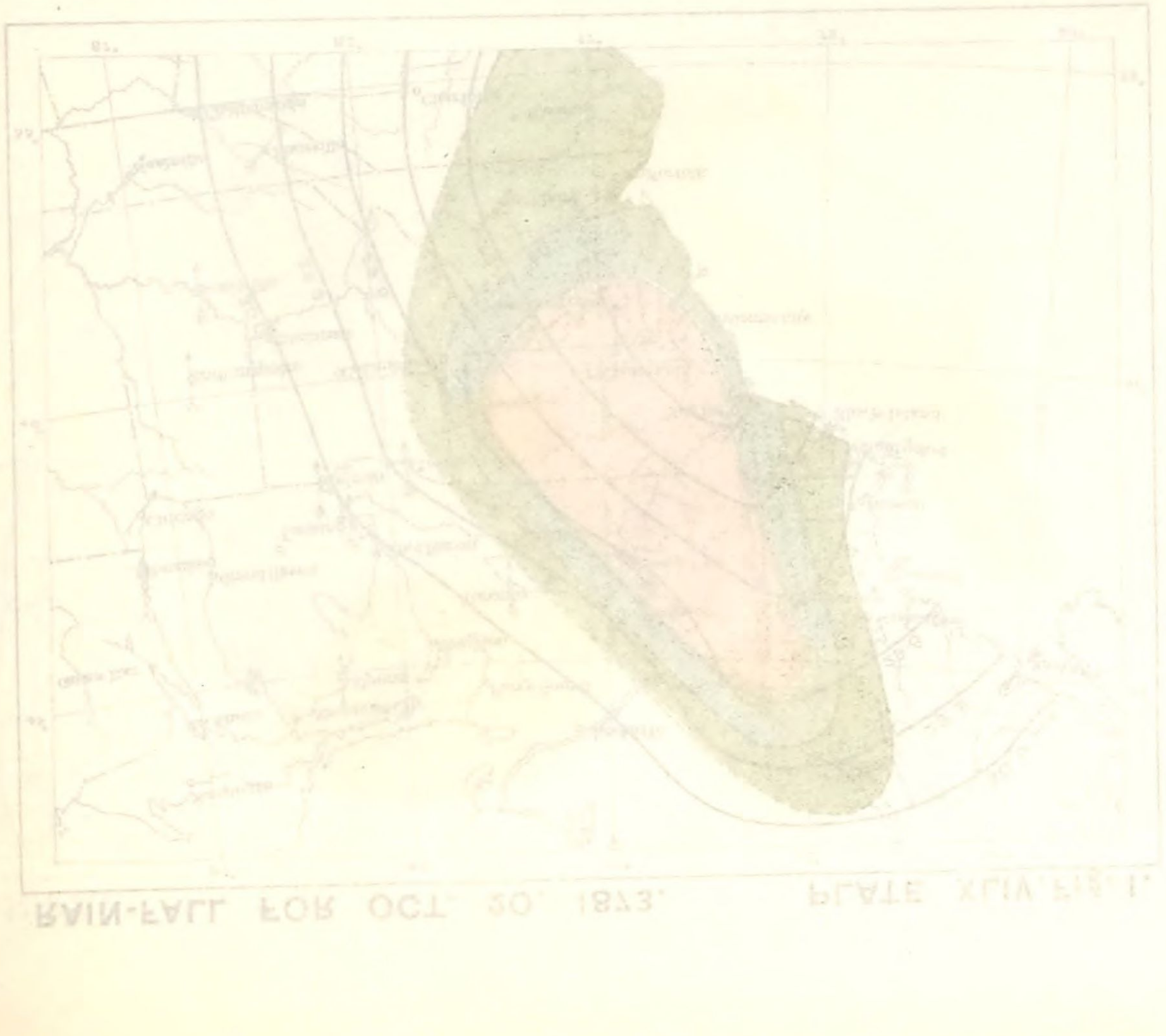
RAIN-FALL FOR MARCH 8, 1877. 4.35 P. M. Fig. 2.



JULIUS BIEN & CO. PHOTO LITH.

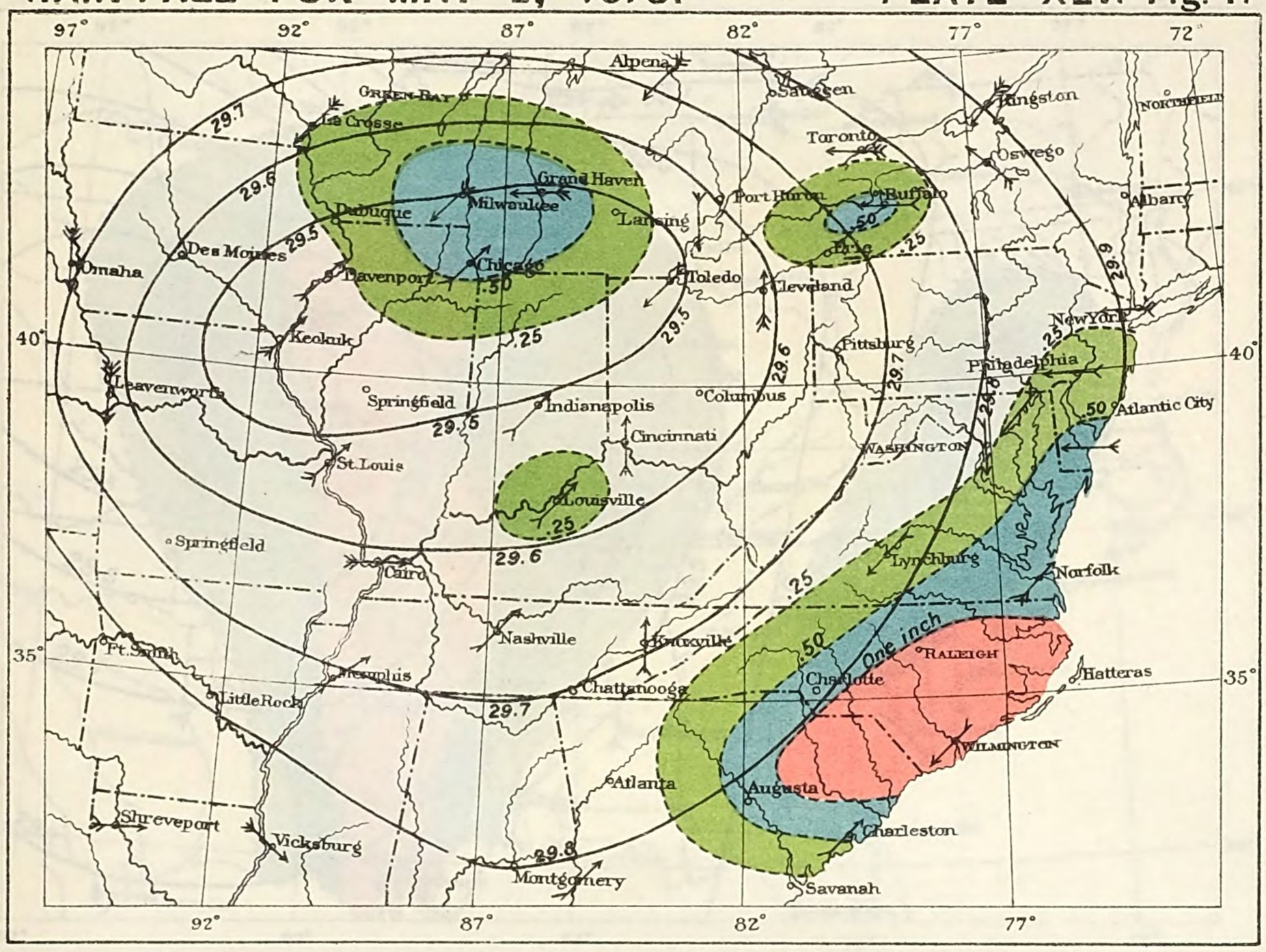


RAIN-FALL FOR MARCH 8 1873 7 TO 8 P M

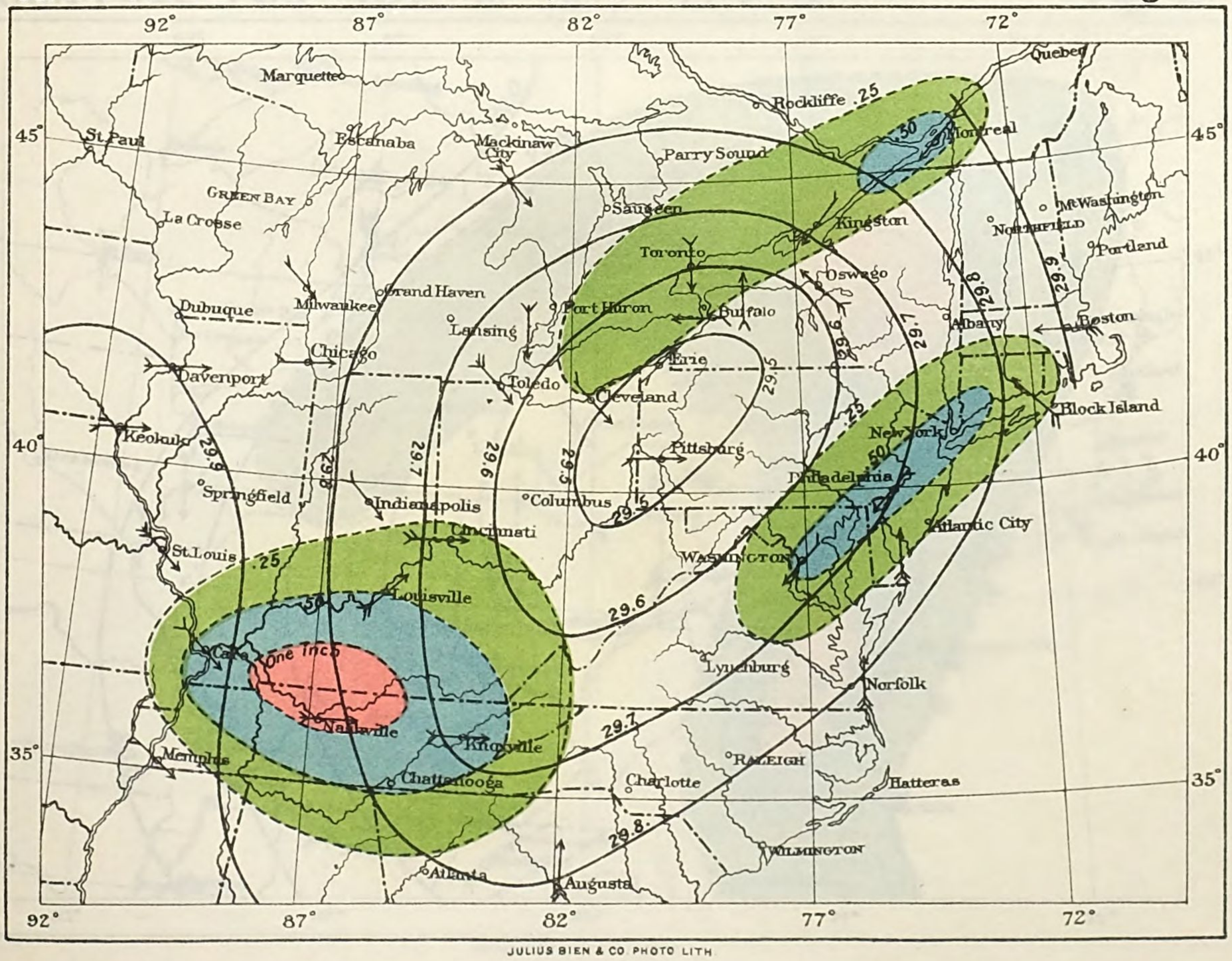


RAIN-FALL FOR OCT. 30. 1873. PLATE XLIV FIG 1.

RAIN-FALL FOR MAY 2, 1873. PLATE XLV. Fig. 1.



RAIN-FALL FOR NOV. 24, 1873. 7.35 A. M. Fig. 2.



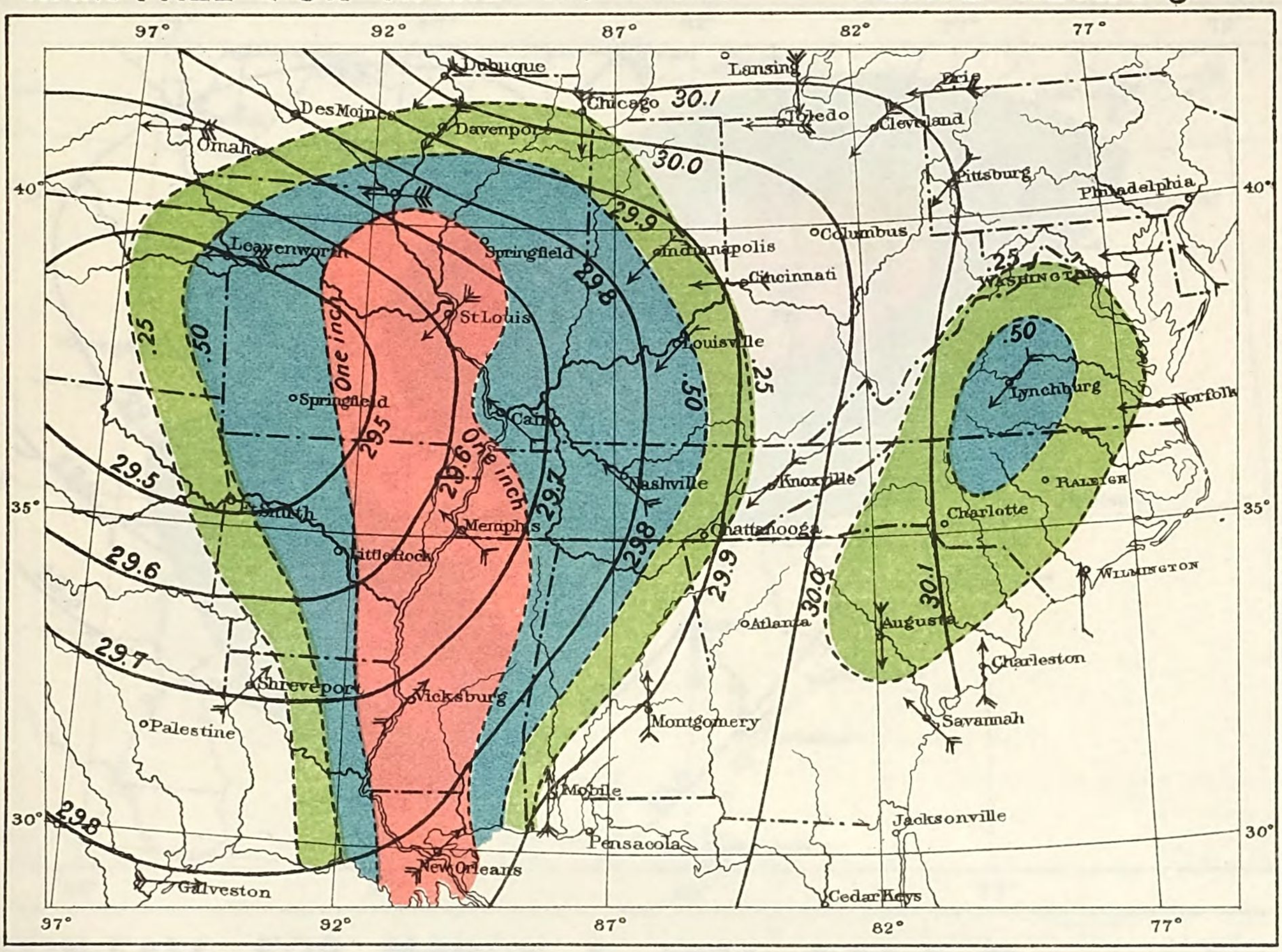
JULIUS BIEN & CO. PHOTO LITH

RAIN-FALL FOR NOV. 24 1923 7.32 A.M.

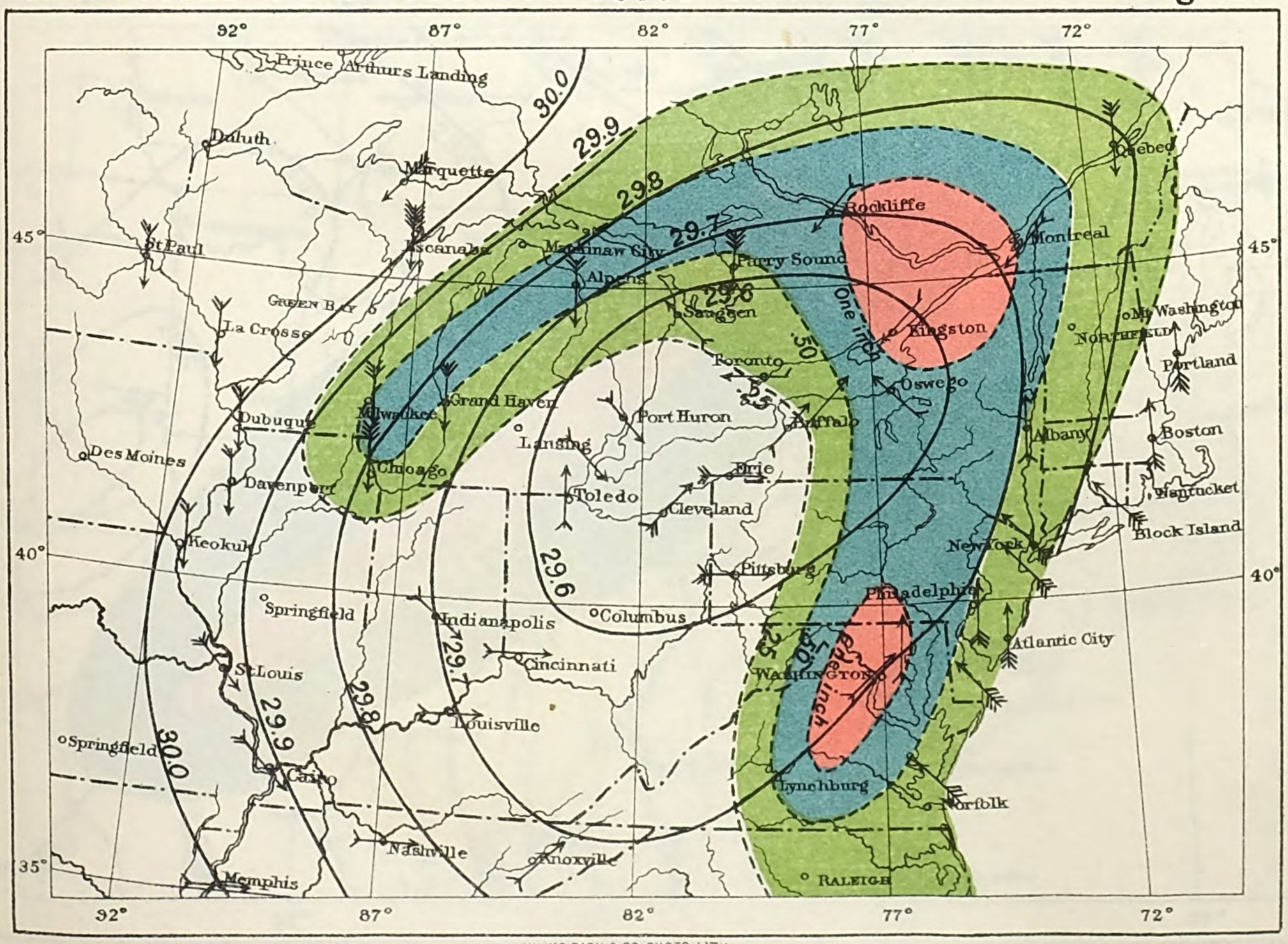
Fig 5

RAIN-FALL FOR MAY 5 1923

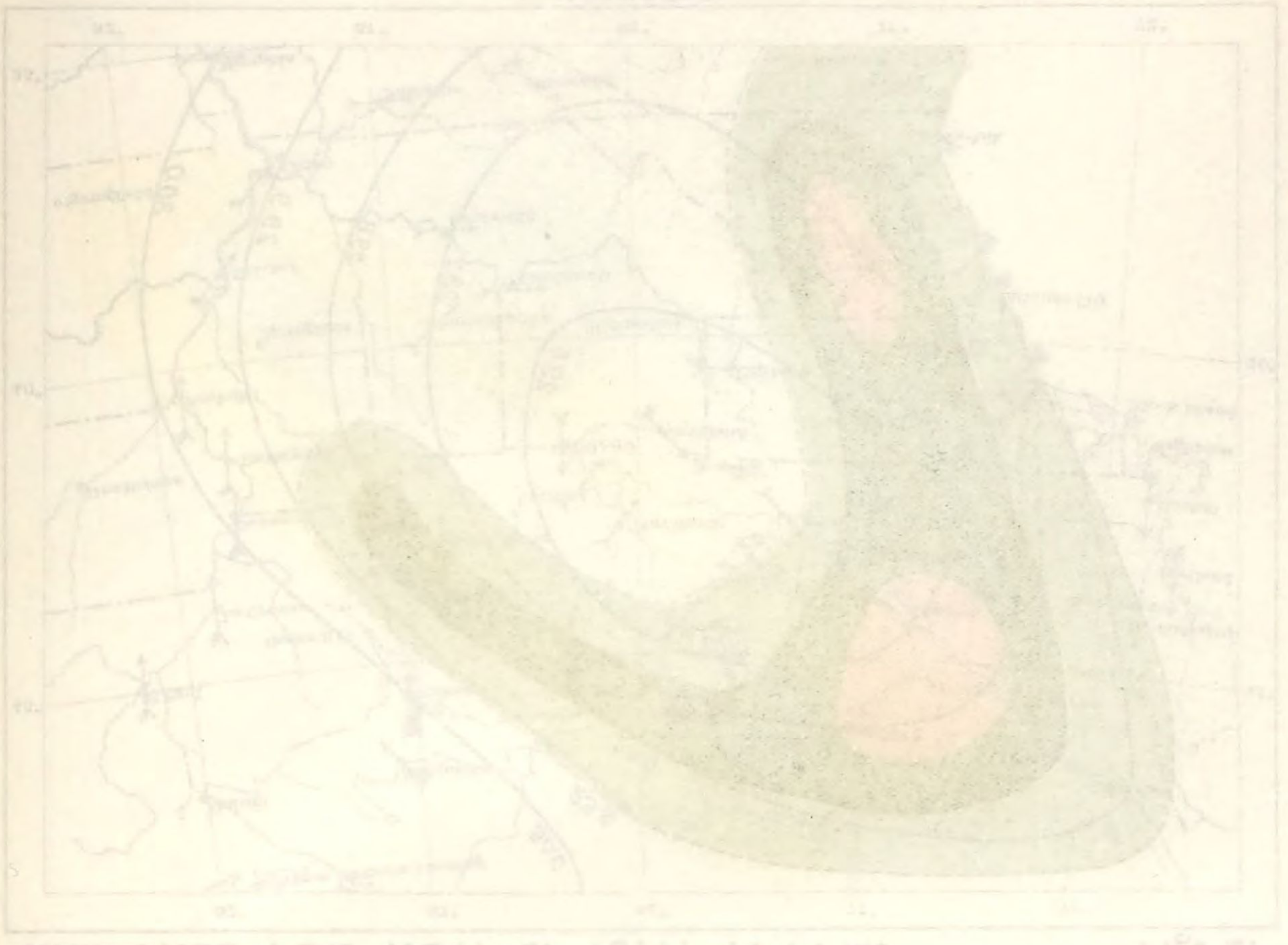
RAIN-FALL FOR APRIL 19, 1874. PLATE XLVI. Fig. 1.



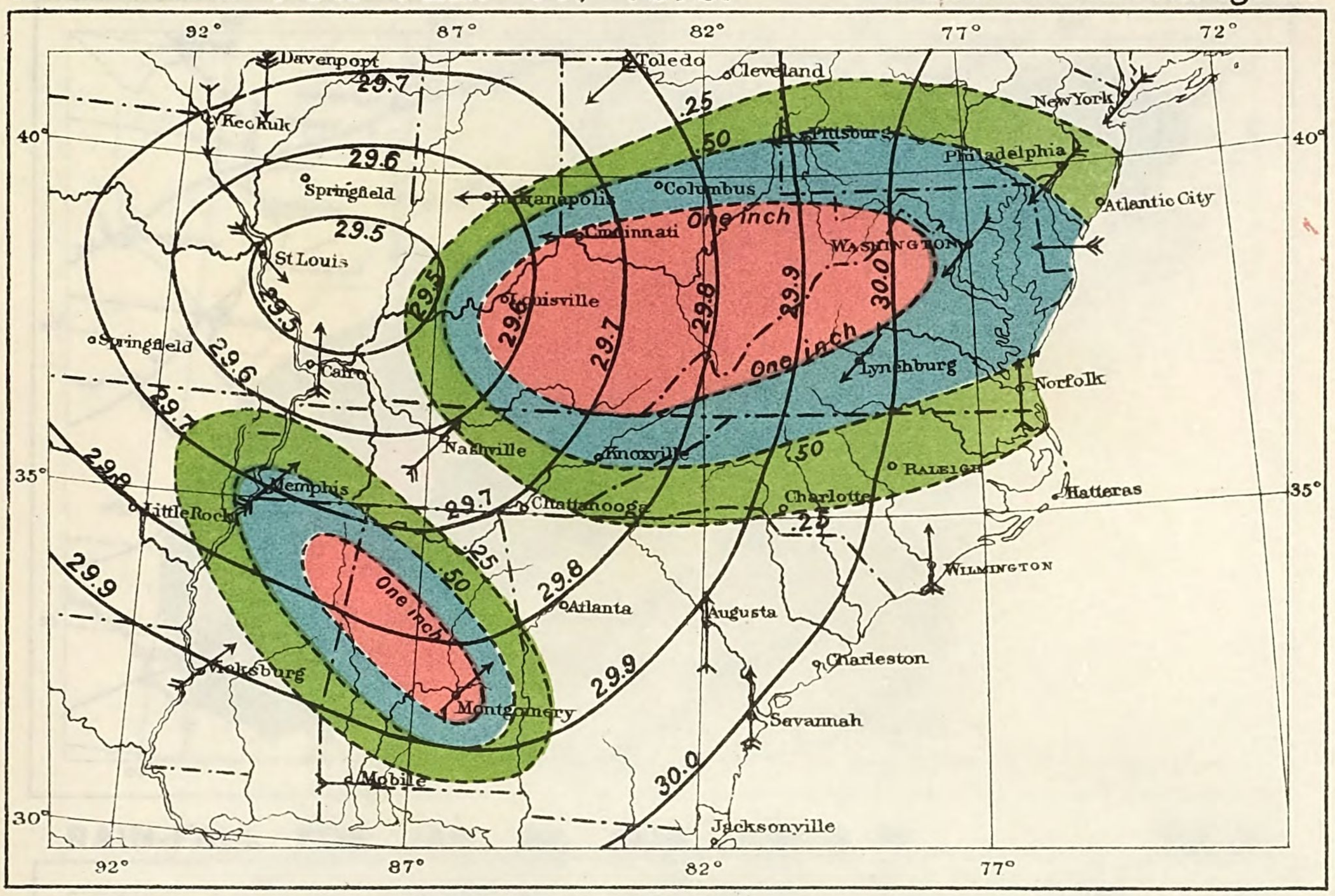
RAIN-FALL FOR NOV. 8. 1877. 11 P. M. Fig. 2.



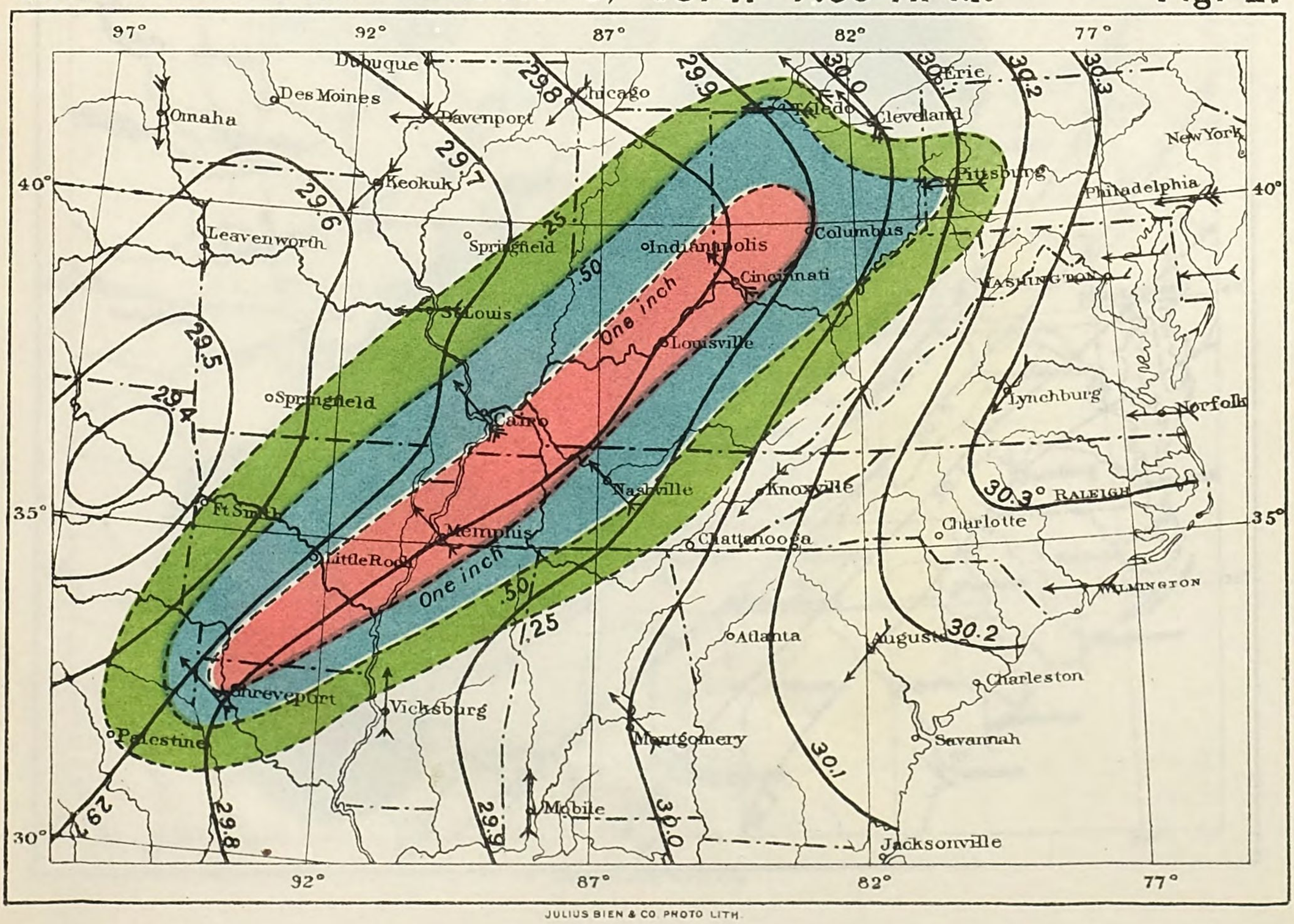
JULIUS BIEN & CO. PHOTO LITH



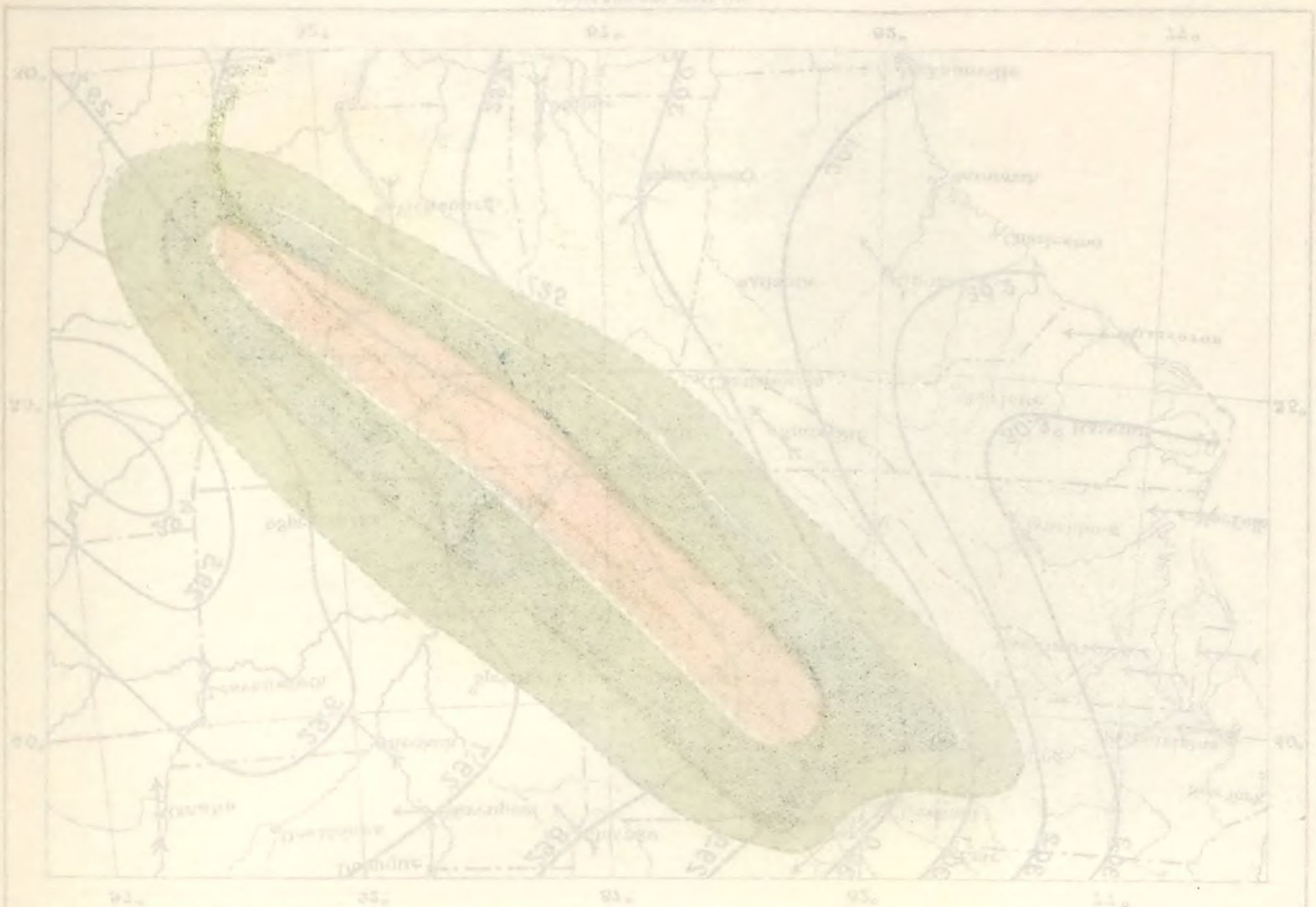
RAIN-FALL FOR FEB. 16, 1873. PLATE XLVII. Fig. 1.



RAIN-FALL FOR MARCH 6, 1874. 7.35 A. M. Fig. 2.



JULIUS BIEN & CO. PHOTO LITH.

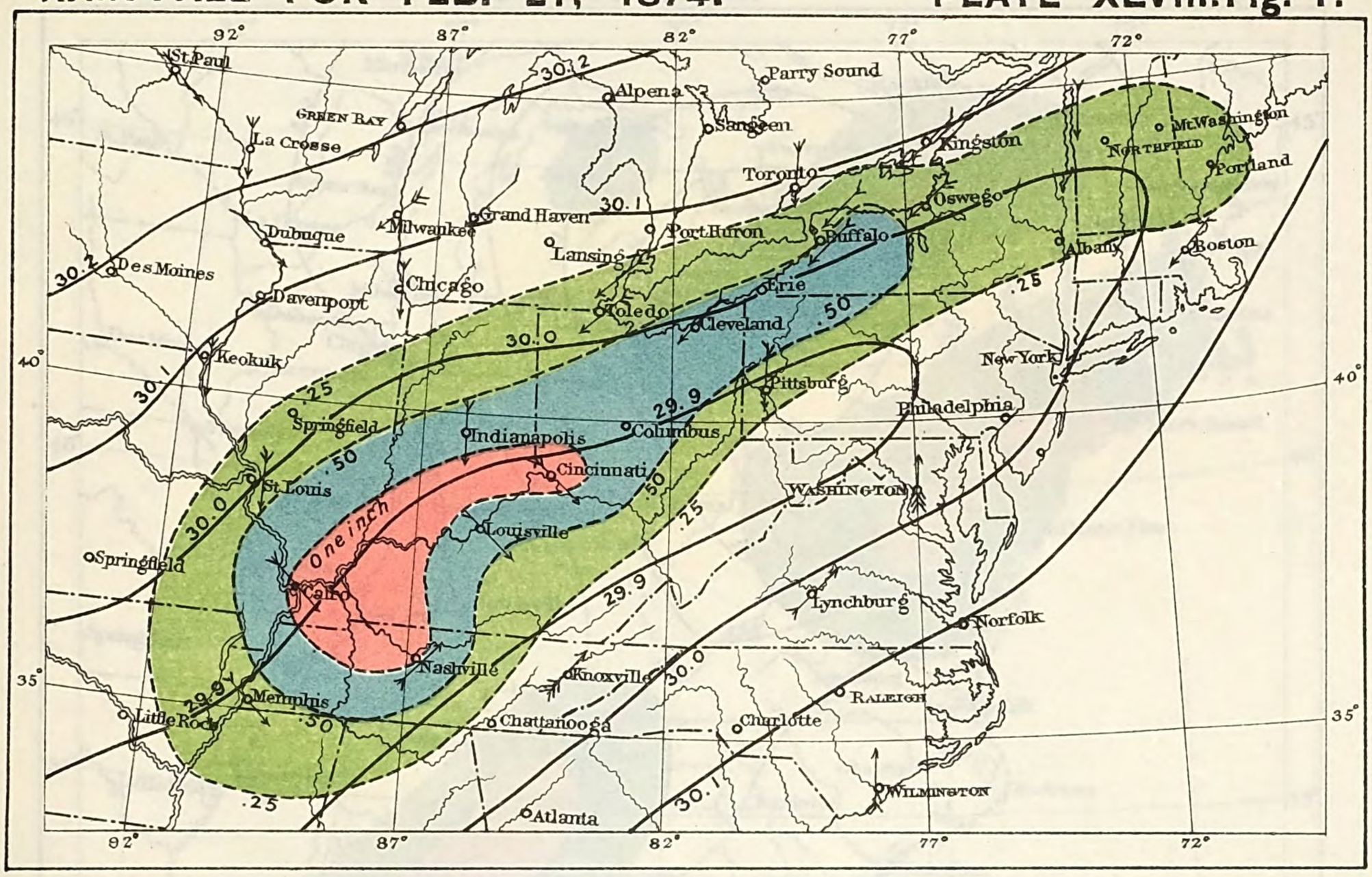


RAIN-CAST FOR MARCH 8, 1874, 7.32 A. M. FIG. 3.

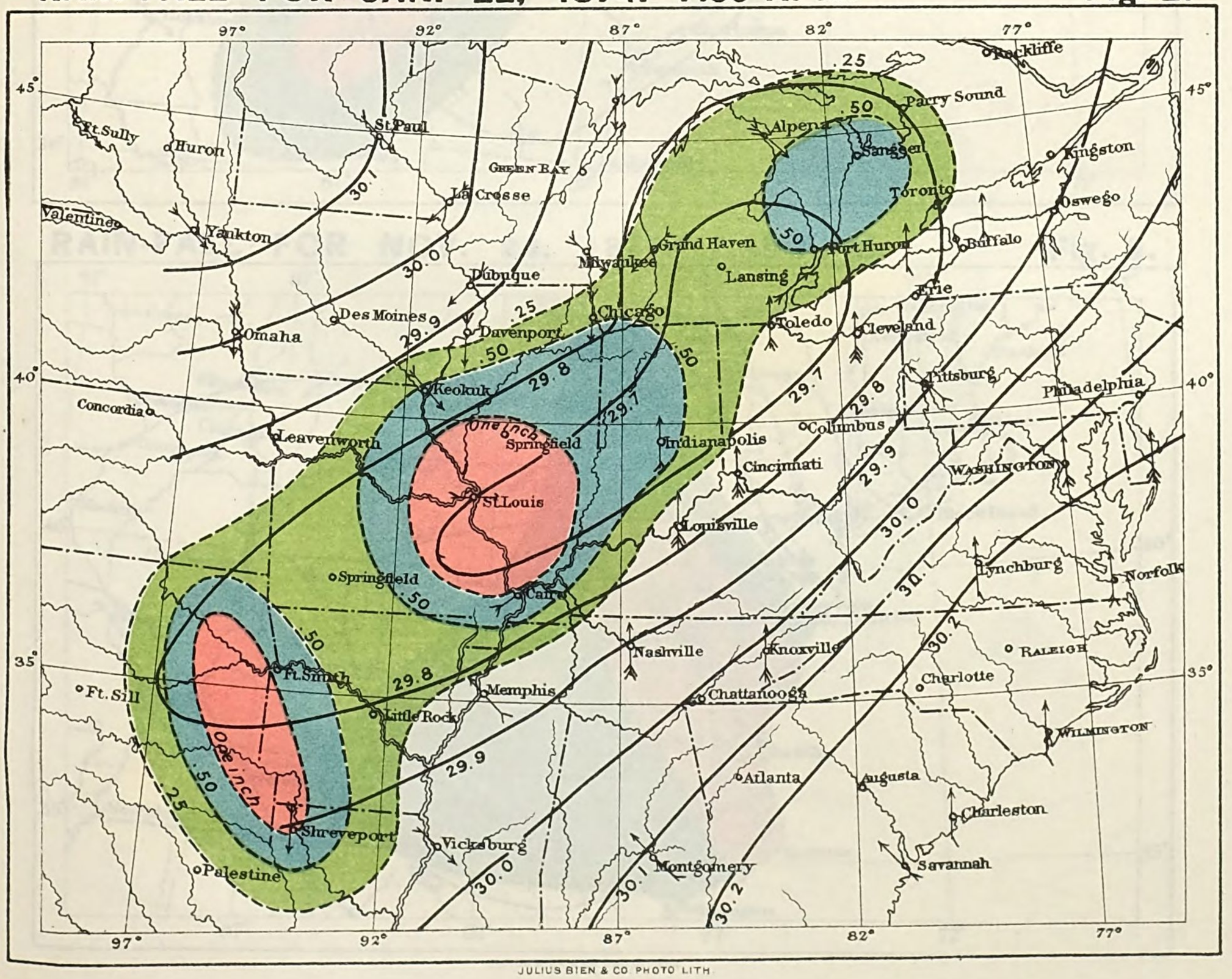


RAIN-CAST FOR FEB. 16, 1873. PLATE XLVII FIG. 1.

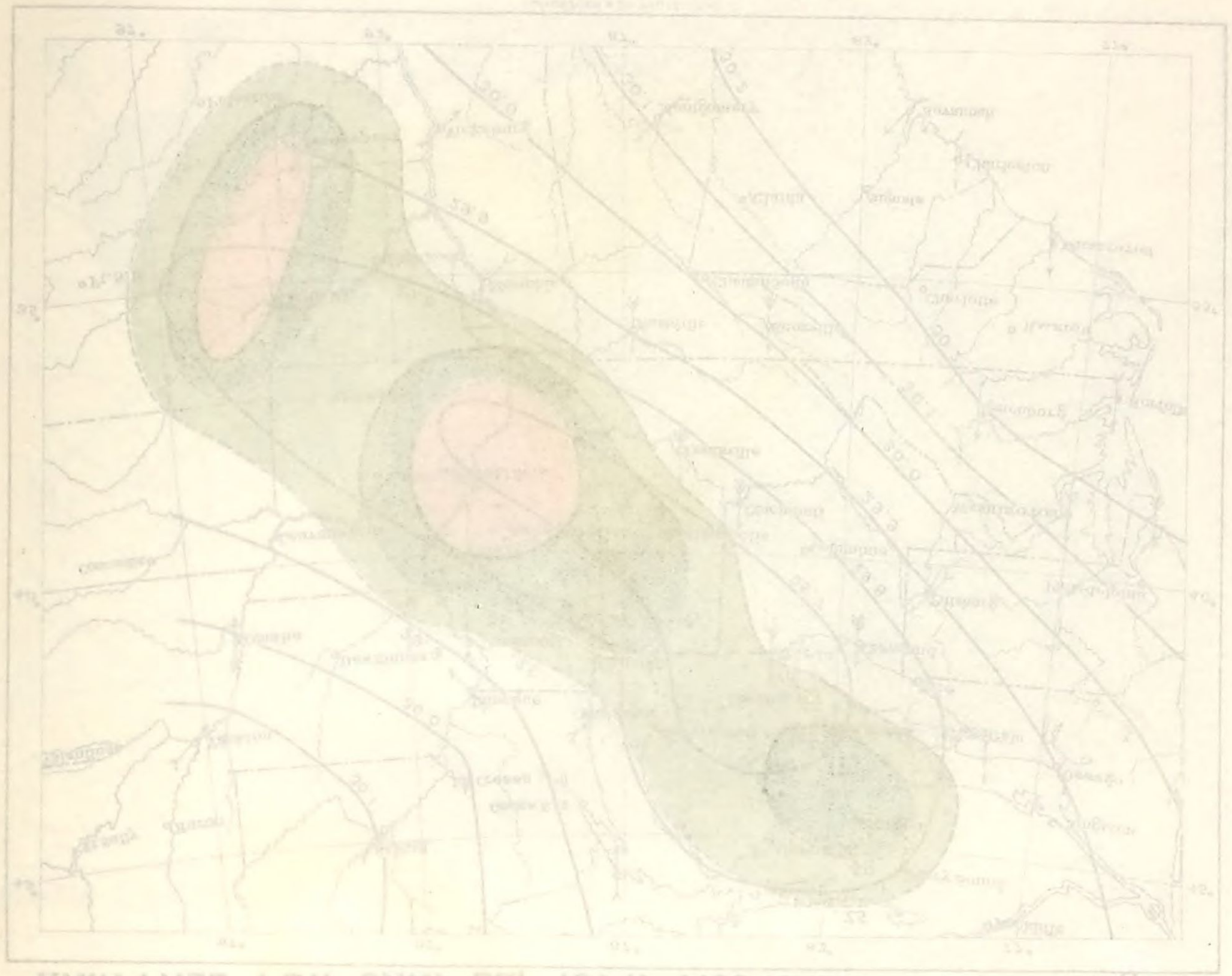
RAIN-FALL FOR FEB. 21, 1874. PLATE XLVIII. Fig. 1.



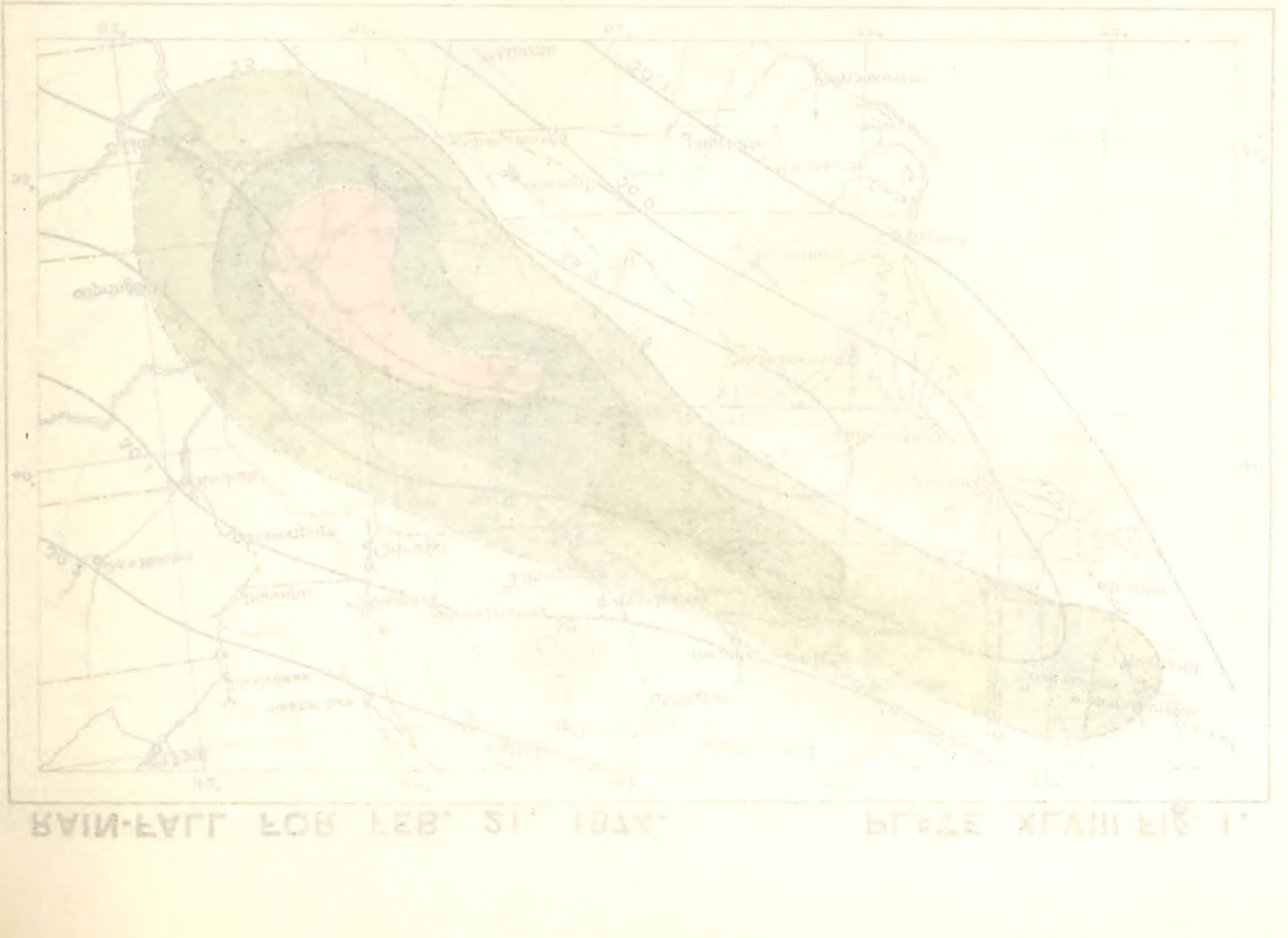
RAIN-FALL FOR JAN. 22, 1874. 7.35 A. M. Fig. 2.



JULIUS BIEN & CO. PHOTO LITH.

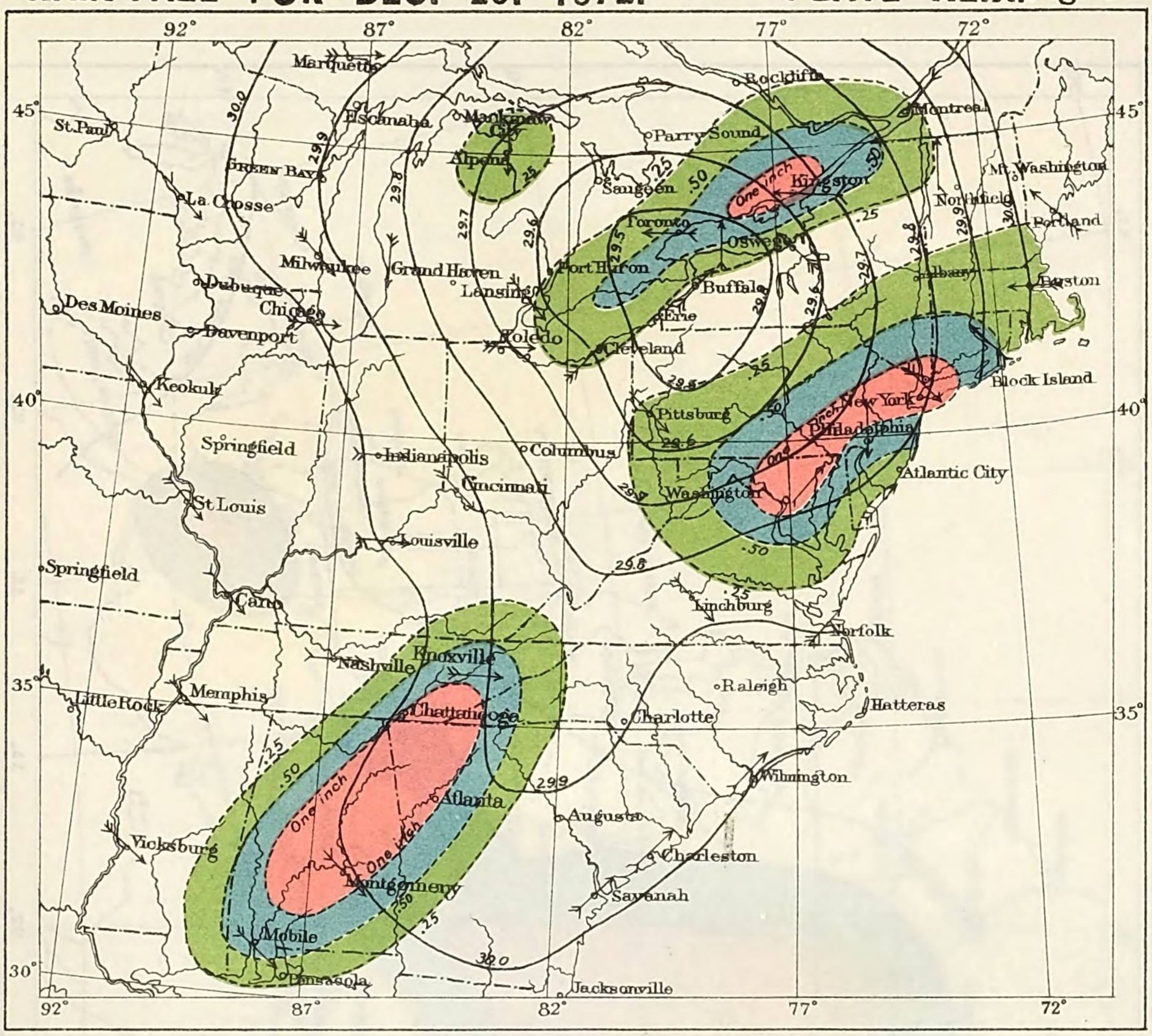


RAIN-FALL FOR JAN. 22, 1874. 7.32 A. M. Fig. 5.

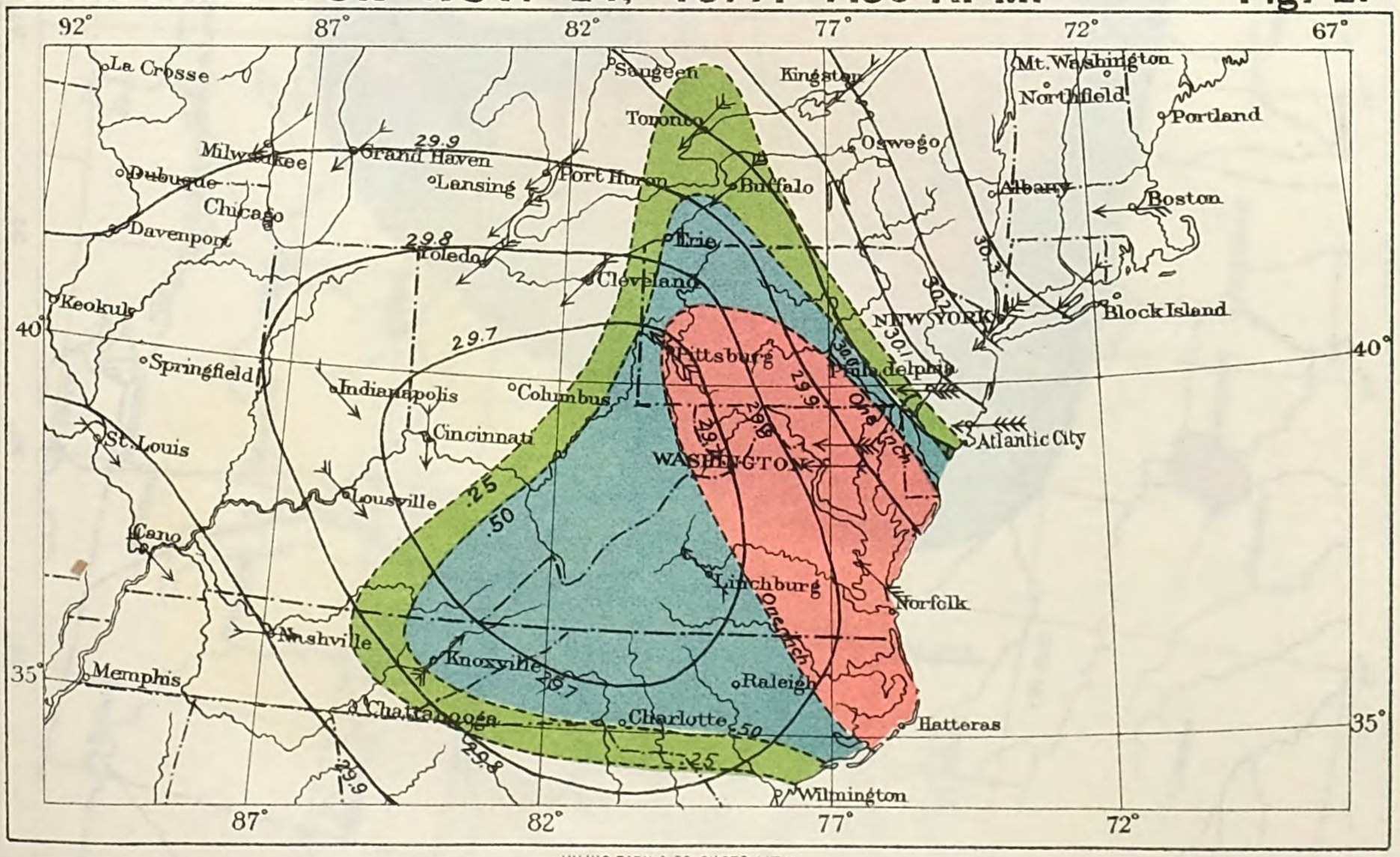


RAIN-FALL FOR FEB. 21, 1874. PLATE XLVIII Fig 1.

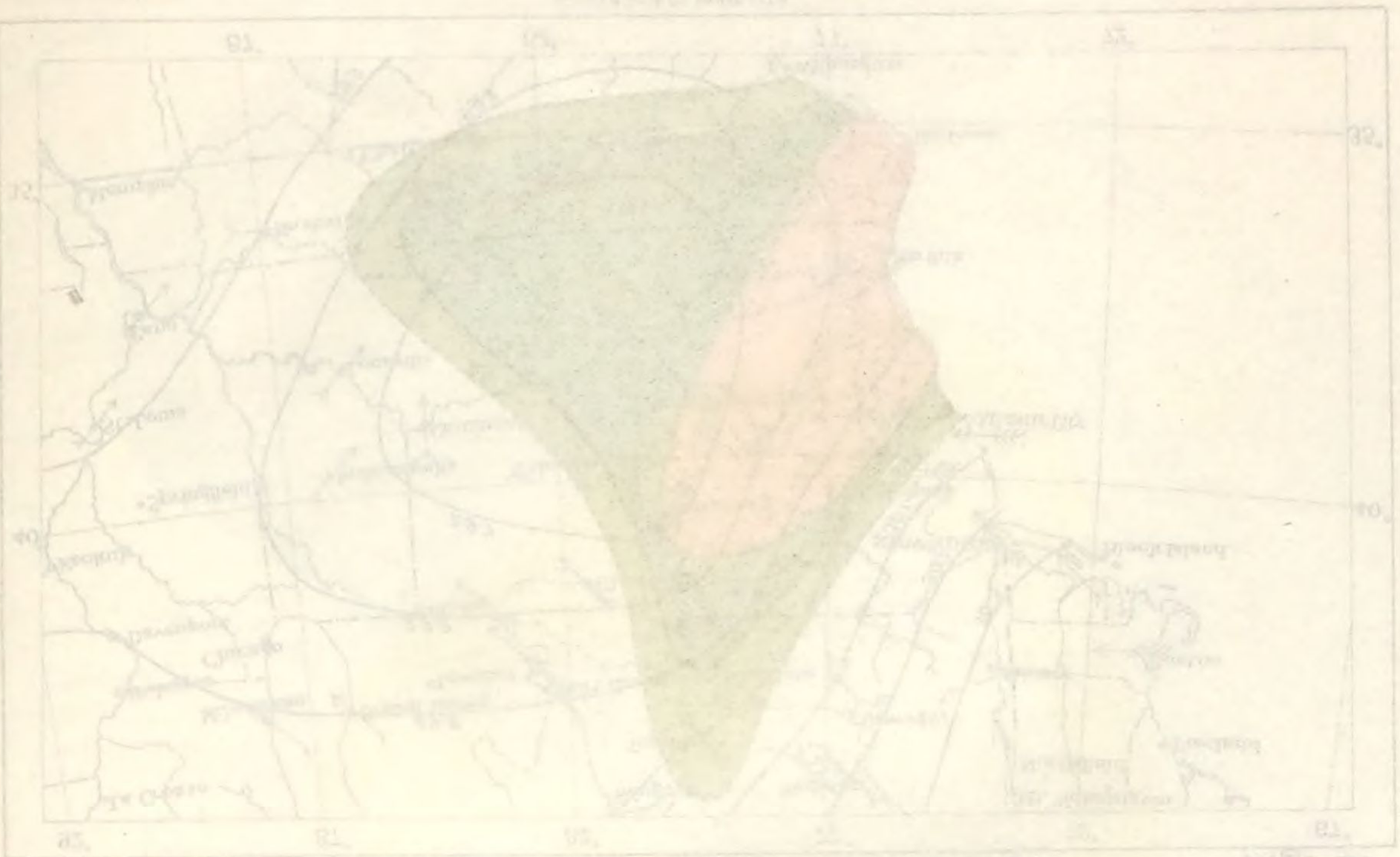
RAIN-FALL FOR DEC. 20. 1872. PLATE XLIX. Fig. 1.



RAIN-FALL FOR NOV. 24, 1877. 7.35 A. M. Fig. 2.



JULIUS BIEN & CO. PHOTO LITH.



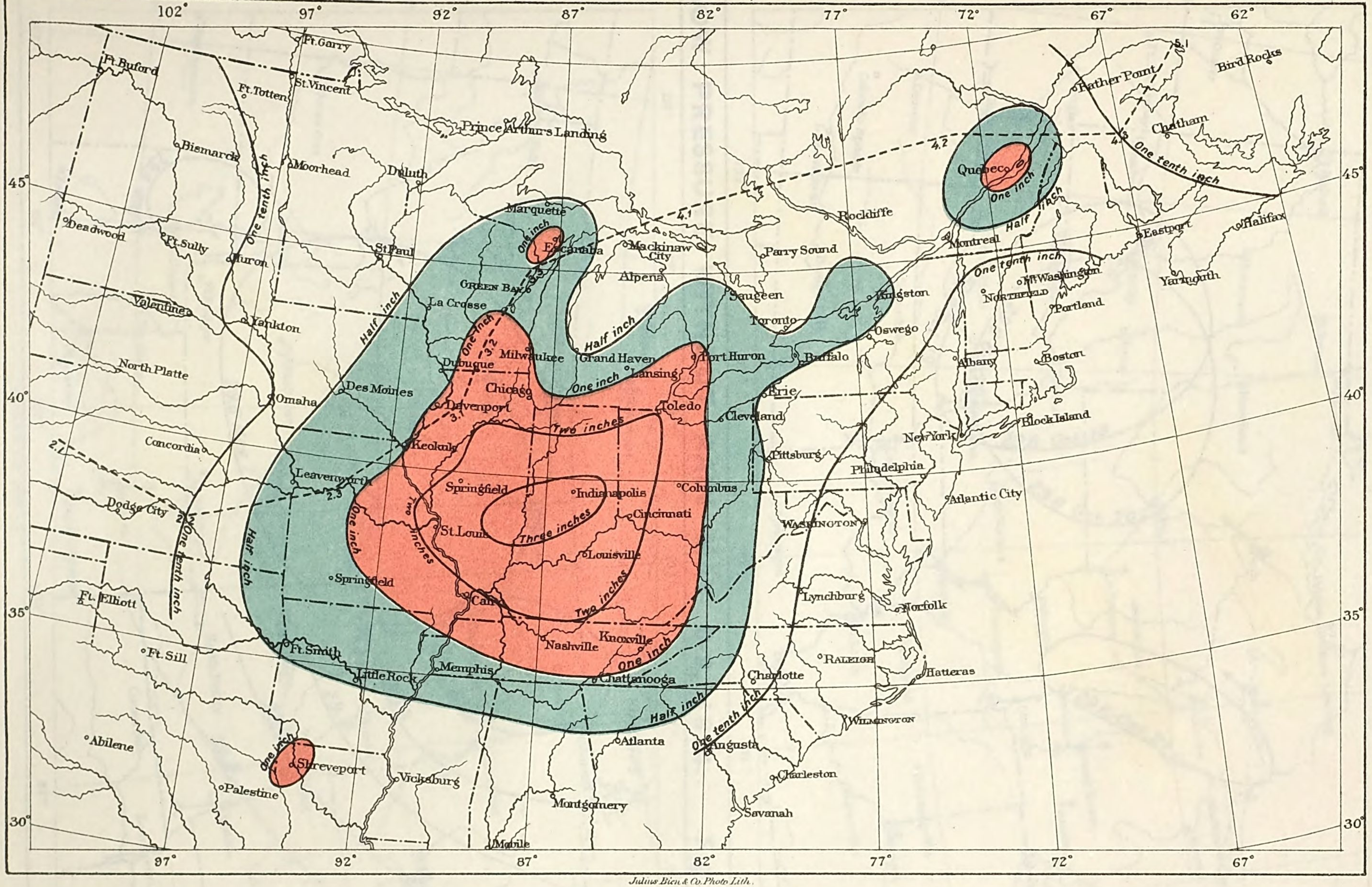
RAIN-FALL FOR NOV. 24. 1872. 7.35 A.M. Fig. 8.



RAIN-FALL FOR DEC. 30. 1873. SCALE 20 MILES = 1"

RAIN-FALL FOR DEC. 1-5, 1873.

PLATE L.



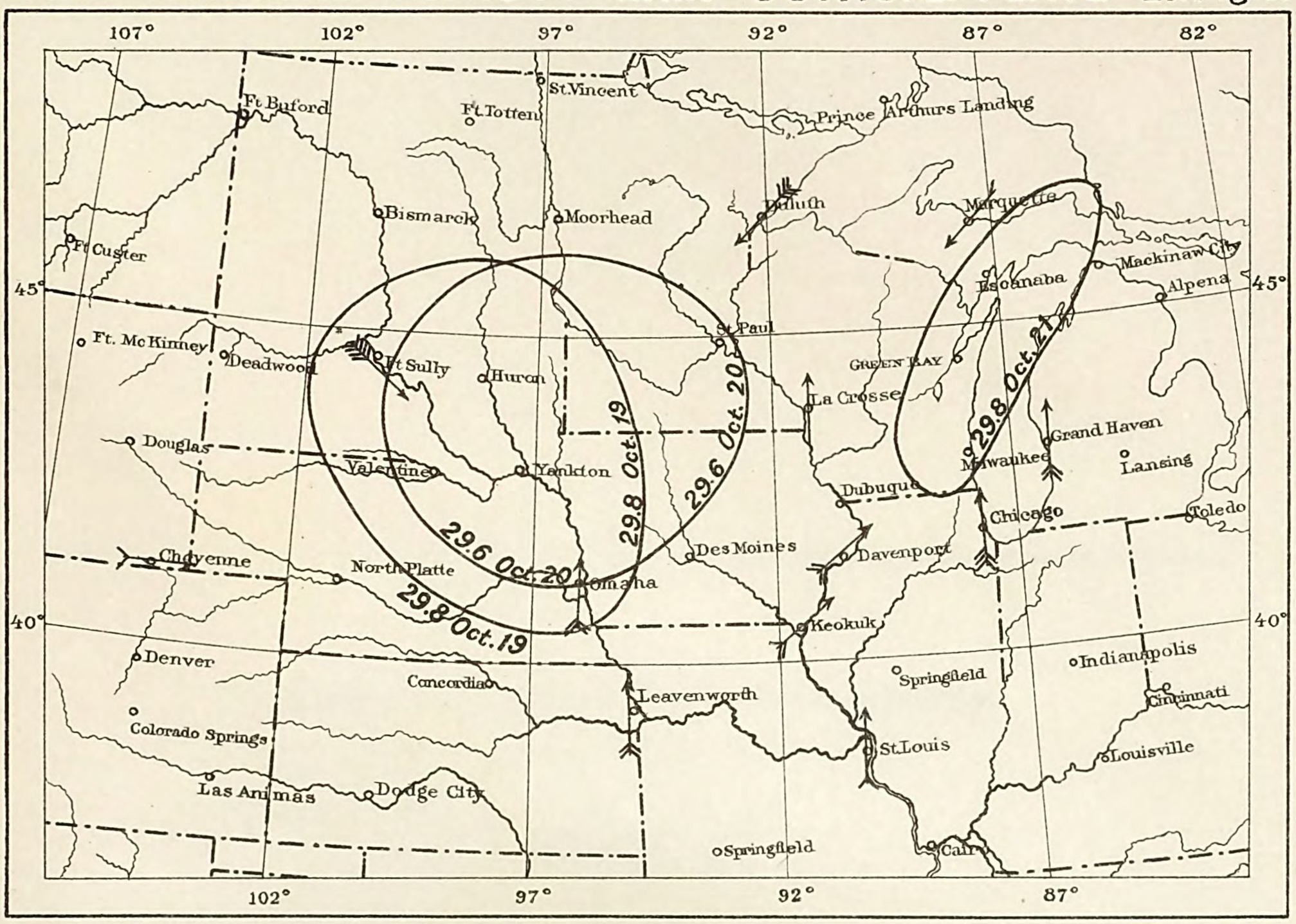
Julius Bien & Co. Photo Lith.



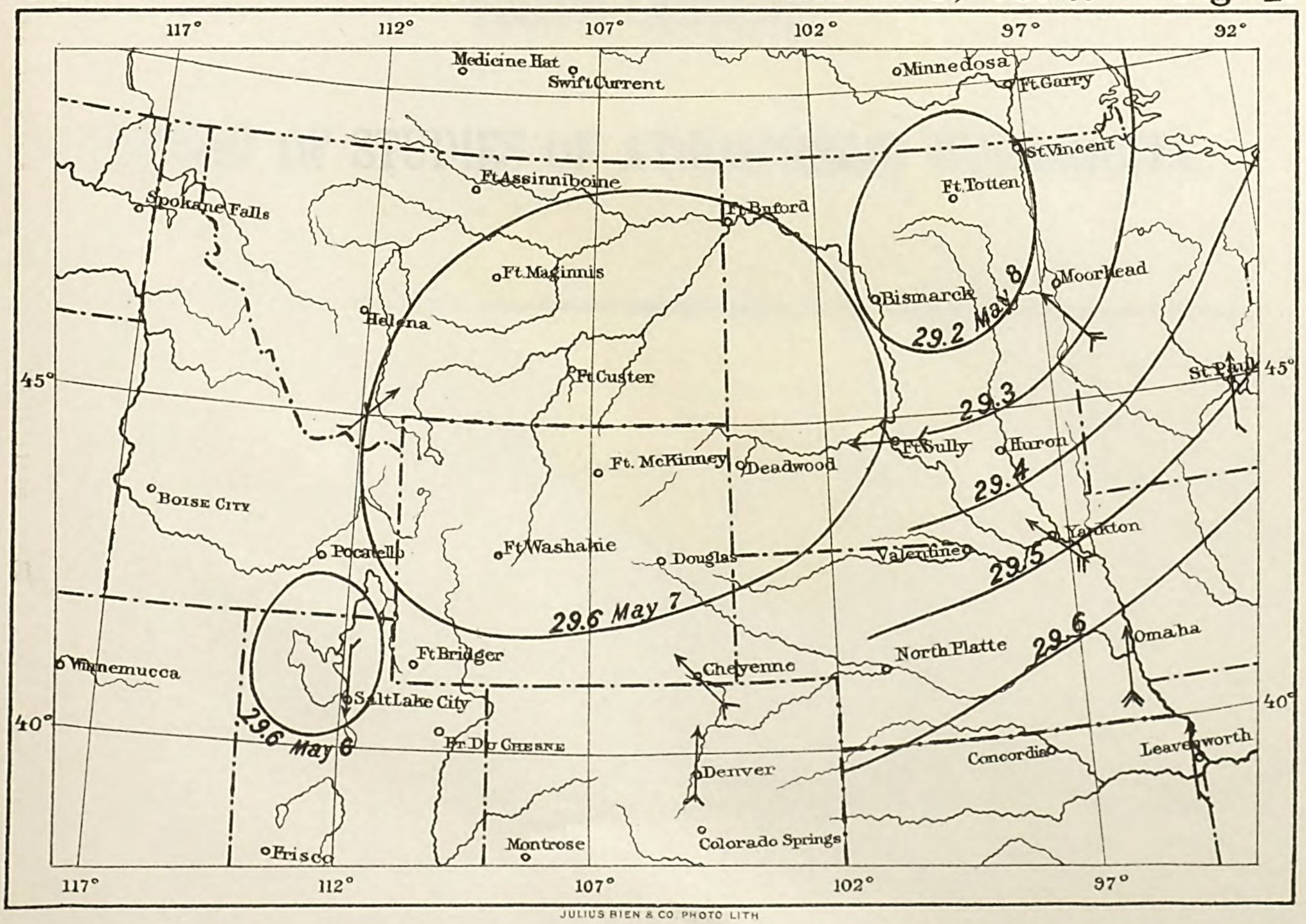
RAIN-FALL FOR DEC. 1-2, 1873.

PLATE I.

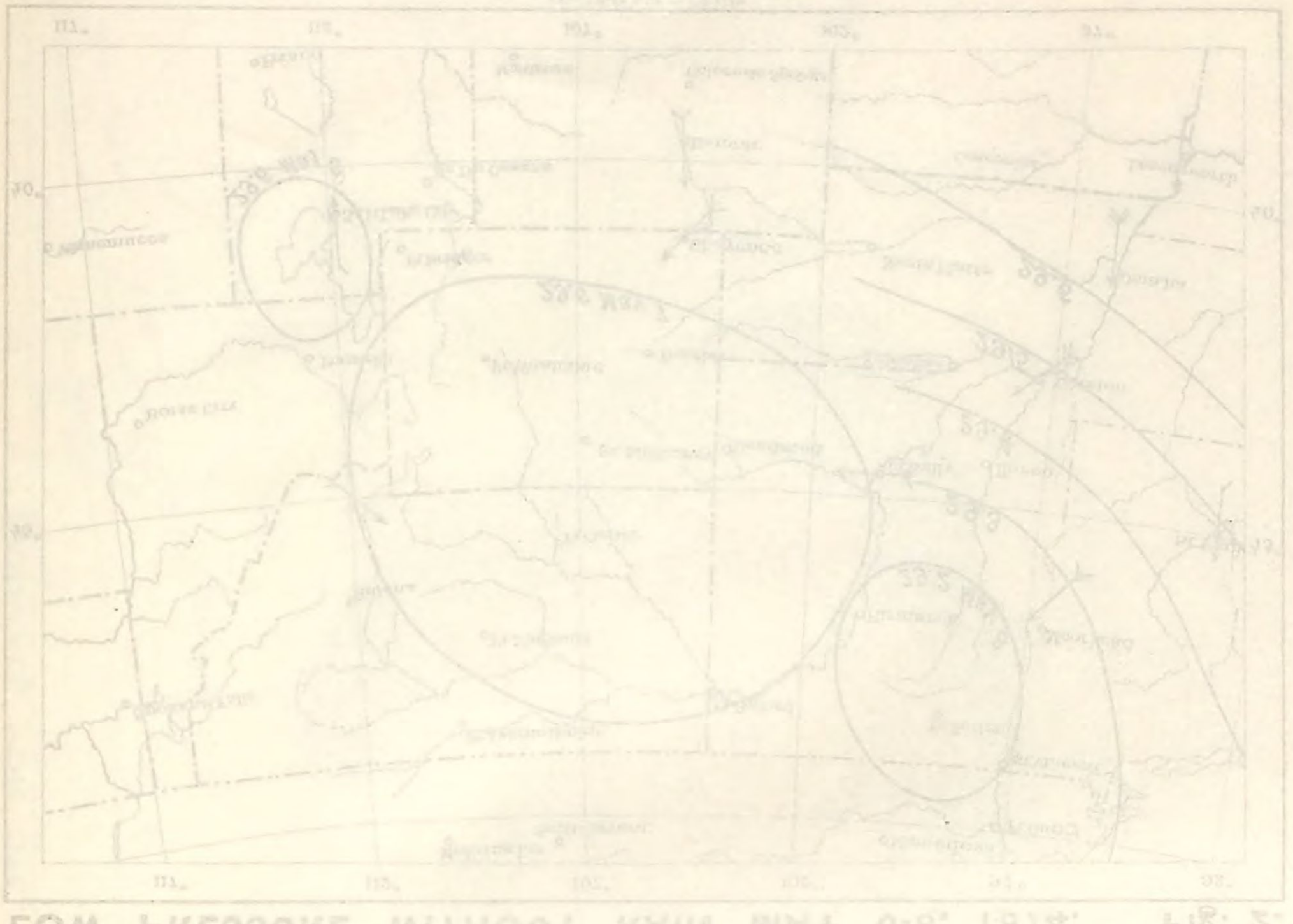
LOW PRESSURE WITHOUT RAIN OCT. 1872. PLATE LI. Fig. 1.



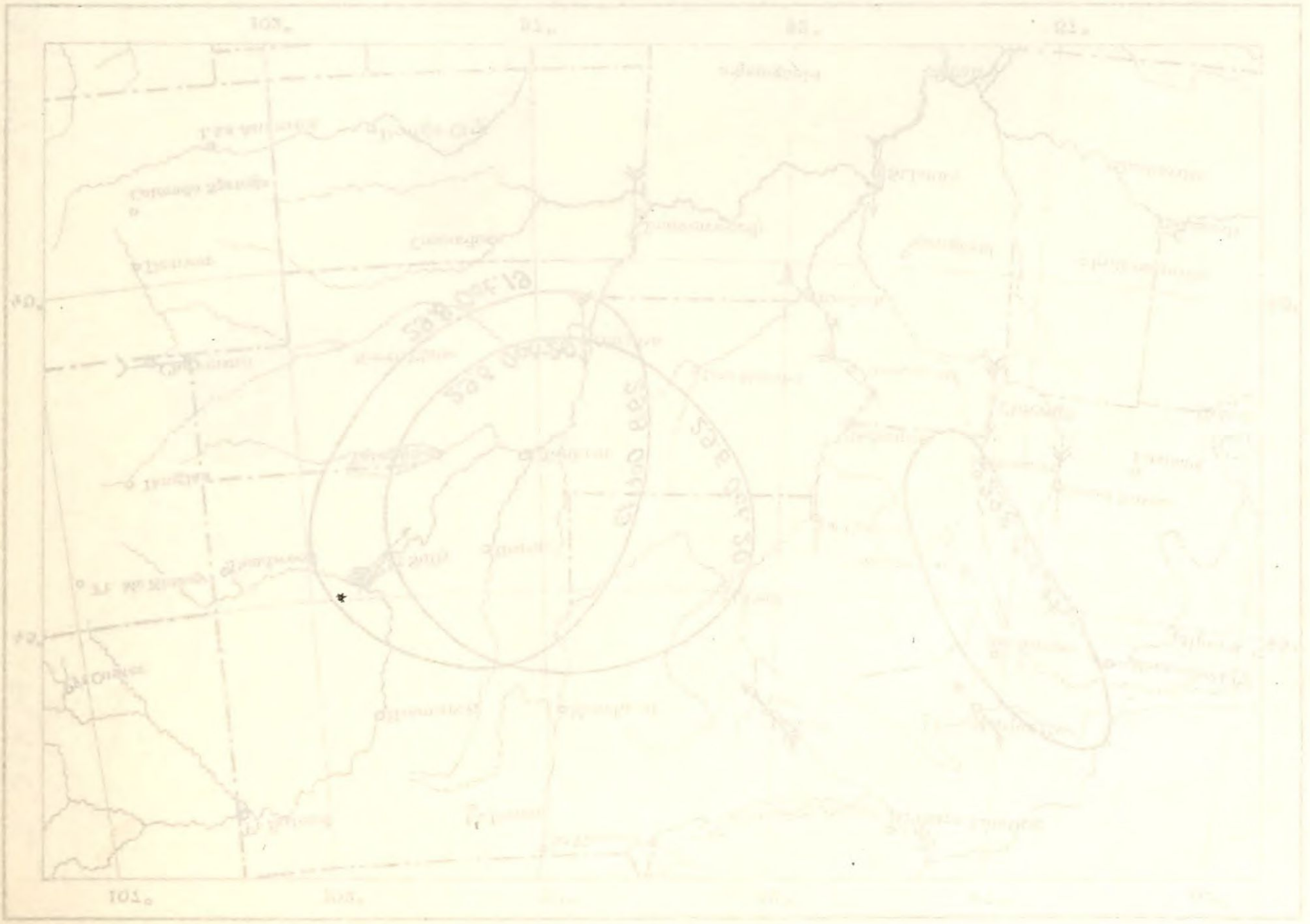
LOW PRESSURE WITHOUT RAIN MAY 6-8, 1874. Fig. 2.



JULIUS BIEN & CO. PHOTO LITH



LOW PRESSURE WITHOUT RAIN MAY 6-8, 1874. Fig. 5.



LOW PRESSURE WITHOUT RAIN OCTOBER DATE 11-13.

NATIONAL ACADEMY OF SCIENCES.

VOL. V.

THIRD MEMOIR.

REPORT OF STUDIES OF ATMOSPHERIC ELECTRICITY.

REPORT OF STUDIES OF ATMOSPHERIC ELECTRICITY.

By T. C. MENDENHALL.

[READ BY PERMISSION OF THE CHIEF SIGNAL OFFICER, APRIL 18, 1889.]

INTRODUCTION.

The existence of atmospheric electricity is a modern discovery, yet there is reason for believing that it was utilized as a means of weather forecasting 300 years ago. It is related on good authority that—

> There had existed from time immemorial, in one of the bastions of the castle of Duino, situated in Frione, on the banks of the Adriatic Sea, a pointed rod standing in a vertical position. In summer, when the weather had the appearance of being stormy, the soldier who mounted guard in the bastion, examined the iron rod, and presented to it the point of an iron halbert, which was always ready for this purpose, and whenever he perceived that the iron rod gave sparks or displayed a small gerbe (sheaf) of fire at its point, he rang a bell to give notice to the country people who were working in the fields, or to the fishermen who were at sea, that stormy weather was approaching.

The custom was said to be of great antiquity and is mentioned in a letter dated 1602. It is an interesting anticipation of modern methods not only in the method of making forecasts but in their distribution.

Many phenomena similar to that exhibited by the pointed collector in this first electrical observatory, on the banks of the Adriatic, were known to the ancients and are mentioned by Herodotus, Plutarch, Pliny, and other early historians; and in the commentaries on Cæsar's African war, attributed to Hertius, a storm which was very disastrous to the Roman army is described, during which the shafts of the javelins of the fifth legion seemed to be on fire.

Almost nothing was then known of electricity, although some isolated facts relating to it had been recognized for nearly two thousand years.

Dr. Gilbert, who died in 1603, first studied the subject experimentally and invented the name which it bears. His experiments, prodigious in number, were fertile both in methods and results, and the science was industriously cultivated by those who followed him.

A century and a half elapsed, however, before the identity of lightning and electricity was established or, indeed, suspected.

That light often accompanied exhibitions of electrical effects was noticed by Hawksbee, who made an extended series of experiments on the subject; by Otto Guericke, the famous Burgomaster of Magdeburg, who observed both the light and the sound accompanying electric excitation; and by Dr. Wall, who made a communication to the Royal Society of London in 1708, describing numerous experiments with a long and tapering piece of amber.

He says, "Upon drawing the piece of amber swiftly through the woolen cloth, and squeezing it pretty hard with my hand, a prodigious number of little cracklings were heard, every one of which produced a little flash of light." He further adds, "This seems in some degree to represent thunder and lightning."

Indeed, as the experimental study of electricity continued, continually improved instruments and devices enabled electricians to produce effects of increasing magnitude, so that the resemblance between the electricity of the laboratory and that of nature became constantly more noticeable, and the numerous analogies between the two did not escape the attention of several sagacious observers.

Among these was the distinguished Abbé Nollet, and a brief discussion of the subject published by him several years before Franklin's discovery is worthy of quotation. He says:

> If anyone should take upon him to prove, from a well-connected comparison of phenomena, that thunder is, in the hands of nature, what electricity is in ours; that the wonders which we now exhibit at our pleasure are little imitations of those great effects which frighten us, and that the whole depends upon the same mechanism; if it is to be demonstrated that a cloud, prepared by the action of the winds, by heat, by a mixture of exhalations, etc., is opposite to a terrestrial object; that this is the electrized body, and at a certain proximity from that which is not, I avow that this idea, if it was well supported, would give me a great deal of pleasure; and in support of it, how many specious reasons present themselves to a man who is well acquainted with electricity. The universality of the electric matter, the readiness of its action, its inflammability and its activity in giving fire to other bodies, its property of striking bodies externally and internally, even to their smallest parts, the remarkable example we have of this effect in the experiment of Leyden, the idea which we might truly adopt in supposing a greater degree of electric power, etc., all these points of analogy which I have been some time meditating, begin to make me believe that one might, by taking electricity for the model, form to oneself in relation to thunder and lightning, more perfect and more probable ideas than have been offered hitherto.

It remained for Dr. Franklin, one of the most brilliant philosophers in any age, to establish the identity of lightning and electricity.

Within barely 2 years after he made his first experiment in electricity he had formulated the analogies between the two far more completely and more logically than anyone else, and had devised the test to which his hypothesis must be subjected.

The germ of this splendid discovery seems to have existed in his mind during the year 1749, and finally his thoughts took definite form in the following passages, which occur in his notebook under date of November 7 of that year.

> Electrical fluid agrees with lightning in these particulars: (1) Giving light; (2) color of the light; (3) crooked direction; (4) swift motion; (5) being conducted by metals; (6) crack or noise in exploding; (7) subsisting in water or ice; (8) rending bodies it passes through; (9) destroying animals; (10) melting metals; (11) firing inflammable substances; (12) sulphurous smell.
>
> The electric fluid is attracted by points. We do not know whether this property is in lightning. But since they agree in all the particulars wherein we can already compare them, is it not probable they agree likewise in this?
>
> *Let the experiment be made.*

This statement of the problem, marvelous for its brevity and directness, was afterward elaborated somewhat and communicated to his friend, Mr. Collinson, in London, from whom he had received his first "electrical tube."

The novel and ingenious suggestion of drawing lightning from the clouds, and testing its identity with electricity, was soon known throughout Europe, and attracted much attention, especially in France.

The celebrated naturalist, Buffon, seems to have been the first to attempt the performance of Franklin's experiment. He arranged upon a high tower an insulated bar of iron, which he connected with a conductor and a set of electrical bells by means of which he might receive notice of the presence of the "electric fluid," and it is said that "he waited with anxiety for the first storm of thunder."

He had also recommended M. D'Alibard to construct a similar apparatus at Marly, about 6 leagues from Paris.

This arrangement, the first "collector of atmospheric electricity," consisted of an iron rod 40 feet long, sustained by three poles and insulated by means of silk strings and a stool with glass feet.

It was with this apparatus that the experiment was first successfully performed, and curiously enough neither Franklin, to whom belonged the major part of the glory of the occasion, nor Buffon, who had suggested the attempt, nor D'Alibard, who had erected the apparatus, was present. The longed-for thunder storm came during the absence of the latter, and one Coiffier, a joiner, to whom the care of the "thunder rod" had been intrusted, was the first to draw a spark from the charged

conductor. He was speedily joined, however, by the curate of Marly, for whom he had been instructed to send whenever a thunder storm should approach, that he might serve as an intelligent witness, and shortly after by the entire population of the village, notwithstanding the violent rain and hail.

This was on the 10th of May, 1752, ever memorable in the history of electricity.

On the 18th of May, M. Delors, of Paris, was successful in collecting considerable quantities of electricity by means of a bar of iron 99 feet high, insulated upon a cake of rosin 2 feet square and 3 inches thick, and on the 19th of May, Buffon was rewarded by the passage of a storm cloud near enough to his newly established electrical observatory to enable him to draw several electrical sparks from his insulated conductor.

These experiments were made before Franklin had himself carried out his own suggestion; but in June, 1752, without the knowledge of what had been accomplished in France, he raised his famous electrical kite, with results familiar to every schoolboy.

Immediately a host of observers all over Europe, and others besides Franklin in America, repeated this experiment in various forms, and the identity of the electricity of the atmosphere was established beyond question.

In these earlier experiments it was only attempted to obtain manifestation of electricity during the passage of storm clouds, known as thunder clouds, but the question of the possibility of electrical effects from the atmosphere in its usual or normal condition very soon presented itself. Monnier, who had studied the electricity of the air during thunder storms, was the first to discover that very often, and perhaps always, a quantity of electricity existed in the atmosphere, when there was no appearance of thunder. He communicated the results of his experiments to the Royal Academy of Sciences at Paris on the 15th of November, 1752.

This phase of the subject was immediately taken up by the Abbe Mazeas, who made an extensive series of experiments in the summer of 1753. His "collector" consisted of an iron rod 370 feet long, raised 90 feet above the ground. It was insulated by silken cords, and in lieu of an electrometer or electroscope, a large key was suspended to the end of the rod. He attempted, however, to compare the intensities at different times by measuring the distance through which light bodies would be attracted by his conductor.

With this apparatus he made numerous experiments, reaching results many of which were trustworthy, while in others he was misled by the imperfections of his equipment.

Among the observers of this period, none were so industrious as Signor Beccaria, and, indeed, it may almost be said that the foundations of our knowledge of atmospheric electricity were laid by him.

Some difficulty was experienced by all of the earlier observers in distinguishing the nature of the electricity of the atmosphere; that is, in determining whether it was positive or negative.

Dr. Franklin devised a simple and elegant method for comparing it with that produced by the friction of a glass rod.

Some European observers, including Beccaria, depended upon the nature of the glow or illumination of a point attached to the conductor. Beccaria used rods and also kites for collectors and found that the higher the rods or the more elevated the kites the stronger the electrification, an observation of great importance.

Having two rods for collecting electricity and conveying it into his house, one of which was 30 feet higher than the other and distant from it about 140 feet, he noted the interesting fact that when a spark was drawn from the higher one the electrification of the other rod was instantly diminished. He observed the appearance of negative electricity during, or rather after, the passage of a thunder cloud, the charge having been positive at its approach, but his apparatus was incapable of revealing the rapid fluctuations in sign which are now known to take place. He was also the author of ingenious theories regarding the formation of clouds, rain, snow, and hail, in which he believed that electricity played an important part. Beccaria was probably the first to attempt to make use of electrical observations in a systematic way as a means of weather forecasting.

All of these studies emphasized the necessity for the use of some more delicate and more accurate method of detecting and measuring atmospheric electricity. As early as 1752, Nollet had employed an electrometer consisting of two simple threads which were separated from each other by

the action of repulsion when the conductor to which they were attached was electrified, the distance of separation indicating the intensity of electrification. This was probably the first attempt to reduce the measure of the intensity to the reading of an angle.

Cavallo substituted two firm metal wires for the threads used by Nollet, and a few years later, in 1784, De Saussure greatly improved this form of electrometer, converting it into an instrument of considerable precision and capable of yielding quantitative results. Small pith balls were attached to the free ends of the fine wires; a scale was arranged so that the degree of separation of the balls could be observed, and by the method of "division of charge" the instrument was calibrated so that its different indications were fairly comparable.

De Saussure's method of collecting at first was by means of a fine silver wire 50 or 60 feet in length, to one end of which was attached a lead ball weighing a few ounces. The other end was attached to the electrometer in such a way that when the ball was cast into the air the wire would be readily detached from the instrument, leaving it charged with the electricity which it had acquired at the moment the limit of the length of the wire was reached.

He found by an ingenious experiment that the charge was not due to the friction of the ball with the air, but a little later he adopted as a collector a conductor terminating in a metallic point which could be placed at different elevations. With this apparatus De Saussure made an extensive series of observations which added largely to the existing knowledge of the subject. He found a diurnal period in the intensity of electrification, observing that it presented two maxima and two minima. He observed the great influence of local surroundings, finding no indication of electricity "in houses, under trees, in streets, in courts, and in general in localities wholly inclosed."

He agreed with Cavallo and other observers in the statement that there was always much stronger electrification in the winter than in the summer.

Volta also engaged himself in the study of the subject, and besides several improvements on the electrometer as used by De Saussure, he hit upon the capital device of using a burning match or some slow-burning combustible on the end of the point attached to his conductor. This greatly increased the rapidity with which the electrometer was charged, and thus caused it to keep more nearly in accordance with the electrical condition of the atmosphere.

Both Volta and De Saussure adopted the evaporation hypothesis in explanation of the origin of the electricity of the atmosphere, affirming that it was due to evaporation from the earth's surface, while Franklin had attributed it principally to the action of the sea.

During the first half of the present century much progress was made in the study of the subject, especially in the improvement of instrumental methods.

Several electrometers were specially designed for use in the study of atmospheric electricity, and systematic and long-continued observations were carried on by a number of European observers. The labors of Peltier deserve especial mention, not only on account of his improvements in instrumental devices, but as well for his careful and painstaking study of principles involved.

He declared, as the result of a well-conducted series of experiments, that the electrification of the conductor was due entirely to induction and not to actual contact with the air.

He used movable collectors and endeavored to protect his apparatus from the inductive influence of surrounding bodies.

Lamont used an electrometer of his own invention in a long series of observations at Munich.

A decided advance was made by Dellman in the construction of an instrument of much merit with which he made observations at Kreuznach, and which has been extensively used elsewhere.

Dellman used a movable collector which was raised and lowered at each observation. The first extensive series of observations on atmospheric electricity in America were made by means of Dellman's instruments by Dr. A. Wislizenus, at St. Louis, Mo., beginning in 1861 and extending through about 11 years.

The principal results of these observations have been included in this report. Dellman's electrometer is capable of giving quantitative results, but only at the expense of considerable time and labor at each observation.

In fact, none of the instruments devised up to the time Sir William Thomson attacked the problem were exactly suitable for continuous quantitative work.

The labors of this distinguished philosopher revolutionized electrostatic measurement. His now universally known absolute electrometers furnished the much desired means of reducing all observation to a common unit and his quadrant electrometer proved to be an instrument combining in itself the widest range of sensibility and the utmost convenience in manipulation. Suited for continuous registration as well as for observations at stated periods it has almost entirely superseded all other forms. The water-dropping collector devised and introduced by Thomson also offers numerous advantages over any other, being almost the only one available in continuous registration. The "burning match" or "lantern" of Volta is, under certain conditions, more desirable, but difficulties of insulation and steady maintenance have prevented its general use.

Thomson's apparatus was established at the Kew Observatory about 1861, and photographic records of potential variations have been maintained with more or less regularity up to the present time. The electrometer has been modified by Mascart, Edelmann and others, and has been extensively used at various points in Europe in meteorological observatories both public and private.

The work of Palmieri, Director of the observatory on Mt. Vesuvius, constitutes, perhaps, the only extensive series of observations made within recent years in which instruments founded on the original designs of Sir William Thomson have not been used.

The origin and development of the series of studies of atmospheric electricity carried on by the Chief Signal Officer may be briefly described as follows:

In 1871, shortly after the beginning of the meteorological work of the service, Professor Lapham of Milwaukee, a well-known scholar who had been influential in the Congressional legislation establishing the Weather Bureau, suggested to General Myer, then Chief Signal Officer, the desirability of making observations upon atmospheric electricity. The entire work of the service being at that time new and its organization necessarily somewhat incomplete, it was not considered wise to undertake the work.

In 1877 Dr. Channing, of Providence, wrote the Chief Signal Officer relative to his own observations of noises heard on the telephone, which was just then being brought to the attention of the public, and suggesting its use in thunder-storm predictions.

This matter was referred to Professor A. Graham Bell, who undertook to consider the construction of special forms of telephonic apparatus adapted to this study.

In the mean time the question of the relation of the electrical conditions of the atmosphere to health conditions had interested medical experts for many years, and in 1879 the American Medical Association appointed a committee and authorized expenditures for the maintenance of electrical observations at several stations for the purpose of medical research. This committee sent a communication to the Chief Signal Officer offering to bear the expense of the necessary apparatus if the latter would undertake the observations, and further correspondence was had on the same subject in 1882 and 1883 between the Chief Signal Officer and Dr. J. N. Toner, of Washington, D. C., and Dr. N. J. Davis, of Chicago, Ill.

All of this correspondence and all questions pertaining to the subject had been referred from time to time to Cleveland Abbe, professor and assistant in the office of the Chief Signal Officer, who has served as meteorologist since the establishment of the Weather Bureau.

Having expressed to General Hazen, then Chief Signal Officer, the belief that in addition to the importance of the subject from a medical standpoint, it was worth while for the service to inquire whether electrical disturbances would be of any service in weather forecasting, especially in the case of thunder storms or tornadoes, Professor Abbe was authorized to consult with Professor H. A. Rowland of Johns Hopkins University, one of the first authorities on the subject, and to request him to devise some plan by means of which observations of real value might be made at the stations occupied by the weather service, so that the offer of the American Medical Association might be accepted. Professor Rowland took an active interest in the matter, and at the International Congress of Electricians assembled at Paris in 1881, to which he was a delegate from the United States, he moved the formation of an international commission for the purpose of organizing and directing an investigation of atmospheric electricity. Such a commission was ordered, some other duties relating to the study of earth currents, electric registration of meteorological phenomena, etc., being assigned to it.

He also examined the apparatus at Kew and that of Mascart.

On his return, in November, 1881, he communicated the results of his observations to Professor Abbe, expressing some doubt as to the utility of going into the work unless better and more uniform systems could be adopted and the observations could be extended to all parts of the world.

He expressed his willingness, however, to establish an observatory at Baltimore. The subject was again brought to the attention of the Chief Signal Officer, the possibility of obtaining from the investigation some assistance in the prediction of thunder storms and tornadoes being emphasized, and he determined to undertake the study of the subject.

It was arranged that when the class of observers then under instruction at Fort Myer should graduate (June, 1882,) some of its members should be made special students of electricity preliminary to their appointment as special electrical observers.

Through the interest of Professor Rowland, of Johns Hopkins University, and Professor Trowbridge, of Harvard University, the coöperation of these institutions was secured, and Park Morrill, Alexander G. McAdie, and Austin L. McRae, all of the Signal Corps, were sent, the former to Johns Hopkins University and the two latter to Harvard University for the purpose of making preliminary studies and observations, under the special direction of Professor Rowland at Baltimore and Professor Trowbridge at Cambridge. An electrometer with photometric registering apparatus, as designed and arranged by Mascart, was obtained from Paris, and installed in a suitable room specially loaned for the purpose by the authorities of Johns Hopkins University at Baltimore, and the two men sent to Cambridge were granted special facilities for their work by Professor Trowbridge and the authorities of Harvard University.

Under the direction of Professor Trowbridge a good deal of time was spent in the study of different forms of electrometers, some new forms being specially designed and constructed, and experiments were made with different varieties of collectors. Experiments on atmospheric electricity at high altitudes, collected by a kite, were made by McAdie at Blue Hill observatory, near Boston, and communicated to the American Academy of Arts and Sciences in June, 1885. A paper on the subject was also prepared by Morrill and published by the Chief Signal Officer.

Much of the successful beginning of the work must be attributed to the interest taken in the work by Professors Rowland and Trowbridge and to their active and continued coöperation.

The photographic registering apparatus of Mascart arrived in July, 1883, and was shortly after put in operation.

In June, 1884, Professor Abbe was directed by the Chief Signal Officer to visit Baltimore and Cambridge and examine the progress of the work. On his return a letter was received from the Department of State, through the Secretary of War, transmitting to the Chief Signal Officer resolutions passed by the International Congress of Electricians which had held its second meeting in June, 1884.

These resolutions expressed the desire of the Congress that observations be undertaken by all countries, and that such results as might be collected be sent each year to the International Bureau of Telegraph Administration at Berne, which will make a digest of them and communicate it to the various Governments. The subject was also presented to the conference of electricians held in Philadelphia in September, 1884, in connection with the electrical exposition then in progress, by Professor Abbe, who, with Lieut. James Allen, was a delegate from the office of the Chief Signal Officer. Circulars had previously been sent to many prominent electricians, telegraph and telephone companies, and the numerous replies received enabled the Chief Signal Officer to formulate a series of questions which he submitted to the Philadelphia conference through his delegates, Professor Abbe and Lieutenant Allen.

A committee was appointed by the President of the conference, Professor H. A. Rowland, to consider the subject, with instructions to report within three months. The committee consisted of Professor Abbe, chairman, Lieut. James Allen, Professor J. Trowbridge, Dr. W. W. Jacques, Mr. F. N. Gisborne, Mr. W. H. Preece, and Professor F. E. Nipher.

A preliminary report was made by this committee during the session of the conference in which the United States Government was urged to take steps to secure on a larger scale observations of atmospheric electricity and strength of earth currents. Another meeting of the

committee was held in Baltimore early in October, 1884, at which Sir William Thomson, Lord Rayleigh, and Professor Rowland were present as invited guests. At this meeting it was learned through Mr. Preece, who was also a member of the International Commission, that no definite instructions or plan of operations had yet been formulated or agreed upon by that body, and it was agreed that while the whole subject might be considered as yet in its experimental stage, it was of the utmost importance that the studies already undertaken should be pursued with vigor and that the operations under the direction of the Chief Signal Officer should, if possible, be enlarged.

In the latter part of 1884 the writer was appointed by the Chief Signal Officer to assume the direction of the work as a part of his duties as chief of the physical laboratory and instrument division of the office in Washington.

It was determined to extend the operations in the study of atmospheric electricity as soon as possible, provided the necessary appropriation of funds could be secured. Experiments bearing on the question of exposures, collectors, electrometers, etc., were begun in the spring of 1885, although the only available place for the work was quite unsuitable and it had to be carried on under great difficulties.

The nature of the observations was such that it seemed desirable, indeed almost necessary, that the new stations to be established should be located at some educational institution, in connection with a physical laboratory, so that the observer might be constantly advised by and be, in some degree, under the direction of the professor of physics. With this end in view, arrangements were made for the establishment of electrical stations at the following points:

The Office of the Chief Signal Officer, Washington, D. C.
Johns Hopkins University, Baltimore, Md.
Harvard University, Cambridge, Mass.
Yale University, New Haven, Conn.
Cornell University, Ithaca, N. Y.
Ohio State University, Columbus, Ohio.

The station at Cambridge was afterwards removed to the Massachusetts Institute of Technology.

The service is greatly indebted to the governing authorities of all of these institutions, and especially to the following gentlemen:

Professor H. A. Rowland, Johns Hopkins University.
Professor John Trowbridge, Harvard University.
Professor Arthur W. Wright, Yale University.
Professor W. A. Anthony, Cornell University.
Professor E. S. Nichols, Cornell University.
Professor B. F. Thomas, Ohio State University.
Professor E. H. Mark, Ohio Meteorological Bureau.
Mr. B. W. Snow, Ohio State University.
Professor Charles R. Cross, Massachusetts Institute of Technology.

All of these gentlemen not only devoted a good deal of time to the work as it was in progress, contributing valuable suggestions and advice to the observer, but in all instances they furnished rooms suitable for the establishment of the instruments, and in many the instrumental equipment itself, at least up to the time of the arrival of the apparatus purchased by the Chief Signal Officer, and all of this without expense to the Government. The funds available in the office for this work being only sufficient to purchase the necessary apparatus, it is not too much to say that the carrying out of the investigation was only possible through the assistance thus rendered. The importance of emphasizing this acknowledgment of indebtedness is due to the peculiar conditions under which much Government work is done, in virtue of which those engaged in it may accept such favors from the general public, or from public or private institutions, without being able to make any sort of a return in kind.

Of those persons connected with the service who were detailed as observers or who contributed to the work, in one way or another, special mention should be made of Professor Cleveland Abbe, to whom its inception was almost entirely due, Junior Professors Marvin and Russell, who

rendered invaluable assistance in the experimental work carried on in the laboratory as well as in several series of special observations, and the following members of the Signal Corps, who were detailed as observers at the several stations, or who were on duty as assistants in the laboratory during the progress of the work: Dannhauser, Day, Fassig, Hammond, McAdie, McRae, Morrill, Parker, Schultz, and Strong.

Several of these performed special service, and mention should be made here of two somewhat elaborate memoirs of a historic nature, on the electrometer prepared by A. G. McAdie and A. L. McRae. It was originally intended to combine these for publication in this report, but as the information which they contain is now generally accessible, especially in the article on electrometers in the last edition of the Encyclopædia Britannica, it has been thought best to confine the detailed description of instruments to those actually made use of in the investigation.

Mr. McRae also made translations of several important memoirs in foreign languages.

Before the work was fairly under way, difficulties of a serious nature arose out of the question of the right of the Chief Signal Officer to expend money for the purpose of carrying it on, the wording of the act making the appropriation being such that it was thought to be a matter of doubt. Although the Chief Signal Officer entirely approved of the plan of operations, it appeared to be impossible to avoid long delays in procuring the necessary instruments for preliminary studies and for properly equipping the several stations. The location of the laboratory in Washington, although the best available, was entirely unsuitable for actual experimentation, and in spite of efforts to further the work much less was accomplished during the years 1885 and 1886 than would otherwise have been possible. In the latter part of the year 1886, the writer resigned his position in the service, but General Hazen, the Chief Signal Officer, urged that he continue the direction of the work in atmospheric electricity. Accordingly, an electrical station was established at the Rose Polytechnic Institute, Terre Haute, Ind., and Sergeant A. L. McRae, who had for some time been at Columbus, Ohio, was placed in charge as observer.

The death of General Hazen occurring shortly after, his successor, General Greely, who was much interested in the work, continued it as then organized until, on the failure of Congress to make certain appropriations, he was compelled a few months later to reduce the number of stations, maintaining only those at Washington, Boston, Ithaca, and Terre Haute.

It was found necessary to close the station at Baltimore on account of the removal of the physical laboratory to the new building completed in 1887, and Sergeant Morrill was directed to remove the photographic equipment to Boston. Owing to difficulties met with in its installation, continuous registration was not resumed until the summer of 1888. In August of that year all observations were discontinued. It was thought that a sufficient number had been accumulated to decide the question of their use in weather forecasting, and, in fact, their study up to that date gave little encouragement in that direction.

The labor of tabulating and classifying the large number of observations has been entirely performed by Sergeants McRae and Schultz, who were detailed for that purpose by the Chief Signal Officer. The writer wishes to acknowledge the intelligent and conscientious performance of the work in a manner possible only through their familiarity with and interest in it.

In addition to their labor in the preparation of the tables of observations for publication, Sergeant Schultz, whose detail extended beyond that of Sergeant McRae, has constructed all of the numerous diagrams illustrating the results.

In considering the outcome of this work especial attention is requested to the conditions under which it was done. As already stated, before it was really begun, the Chief Signal Officer was constrained, by decisions of Department authorities, to restrict it to an attempt to answer the question, "In the present state of meteorological science can observations of atmospheric electricity be utilized in forecasting the weather?"

No studies or investigations which did not bear upon this question were proper or allowable.

While it is believed that the answer to this query which the results afford fully justifies the time and labor expended, it will be seen that under the circumstances many questions of great scientific interest and of important bearing on current theories as to the origin of the electricity of the atmosphere had to be set aside for those likely to be of immediate practical value.

INSTRUMENTS AND METHODS.

The electrometer.—All of the electrometers used were of the form known as the Thomson quadrant. Several of them were Mascart's modification of the Thomson quadrant, manufactured by Carpentier. The apparatus for photographic registration used at Baltimore, and for a short time at Boston, was constructed by Dubosq. Experience in the use of this led to several modifications as to detail which were made by Sergeant Morrill from time to time on the advice of Professor Rowland.

The Mascart electrometer is so widely known and has been so frequently described that it is unnecessary to insert a description here.

The earlier observations at Cambridge were made by a modified Clifton electrometer, changes having been made to secure greater convenience of manipulation and more ready access to the various parts of the instrument. A multiple quadrant instrument was also designed by Professor Trowbridge and constructed under his direction. It differed from the ordinary form in that each quadrant was compounded of four, placed one upon another. The aluminum needle was also compound, consisting of four single needles attached to the same axis so as to move in the cells formed by the compound quadrants. A light aluminum index placed above the needle moved over a graduated arc so that direct readings of deviations were made.

The importance of securing high insulation of all parts connected with the collector was not at first fully appreciated, and most of the first instruments used were faulty in that respect. A number of experiments were made for the purpose of overcoming this difficulty as well as some others which seemed to be inherent in the Mascart electrometer.

At first, and continuously with the photographic apparatus, the silk fiber suspension was used, the charge being conveyed to the needle in the ordinary way, that is to say, by means of a platinum wire connecting the needle to the sulphuric acid in the shallow glass jar immediately below it. Besides the insulation of the system, which was irregular and sometimes very bad, difficulties appeared with considerable frequency, giving rise to changes in the apparent zero of the needle. Doubtless some of this variability is to be charged to the silk fiber, but much of it is unquestionably due to a sluggishness in the movement of the platinum wire in the sulphuric acid.

It was finally determined to resort to a wire suspension, through which the charge could be communicated to the needle, thus suppressing the connection between the needle and the acid.

The potentials to be measured ranging from zero to some hundreds and often thousands of volts, no great sensitiveness was desirable, and wires of extreme fineness were not necessary. The fixed end of the wire was supported by a brass cap on the glass tube through which the wire passed, and some difficulty was experienced in finding glass of sufficiently high insulating power for this purpose.

The wire suspension in its final form gave very satisfactory results, however, in the matter of insulation, and when properly prepared was more constant in its zero reading.

The dish of sulphuric acid was still retained for the purpose of keeping the inside of the instrument free from moisture. Modifications were also made for securing greater freedom of access to all of the parts of the instrument.

Several instruments of this type were constructed and supplied to several stations, taking the place, at Ithaca, of a Thomson quadrant by White, of Glasgow, the use of which had been kindly allowed by Professor Anthony, of Cornell University, and at Boston of the instruments formerly used at Cambridge. Record should also be made of the fact that a Thomson portable, by Elliot Brothers, was used for a short time in Cambridge, and also at Columbus, Ohio.

Although these instruments were free from the most serious difficulties found in connection with those first used, and were, in the main, satisfactory, they were still somewhat faulty in certain particulars, and in an atmosphere nearly or quite saturated with moisture, their insulation was often lower than was desirable.

Still further improvements suggested themselves, and finally the construction of an instrument embodying all of the modifications of the Mascart pattern, which experience had commended, was confided, through the firm of Jas. W. Queen & Co., of Philadelphia, to the well-known Société Genevoise.

The essential variations from the Mascart pattern are as follows:

The glass tube, to the top of which the suspension wire was attached, was surrounded by another of larger diameter.

The smaller tube screwed into the brass ring cemented to the foot of the larger, and openings were provided in this ring so that when the large tube was screwed to the top of the electrical case, communication existed between the annular space separating the tubes and the interior of the case.

A brass cap was cemented to the upper end of the large tube, long enough to cover entirely the inner tube with its terminal suspension device, and terminating in a short, brass tube to which rubber tubing could be easily attached.

The upper part of this brass cap could be readily removed to afford access to the suspension arrangement at the end of the inner glass tube. The object of thus incasing the tube supporting the suspension wire was to provide for the maintenance of a dry exterior surface.

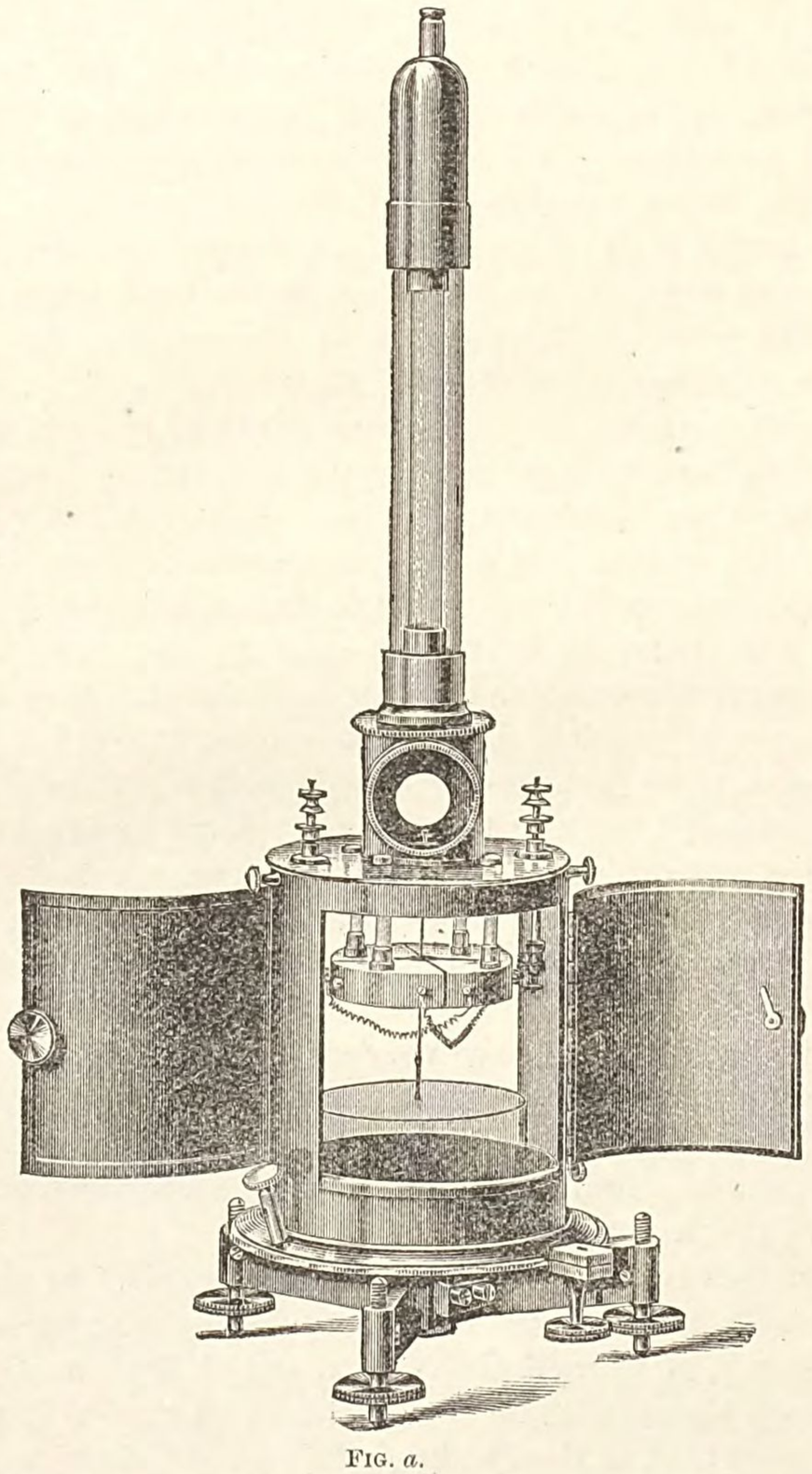


FIG. *a*.

The best obtainable insulating glass proved to be hygroscopic in some degree,but by the above arrangement, air dried by the sulphuric acid within the case could be drawn up into the space between the two tubes, thus securing a dry atmosphere on both sides of the supporting tube. This suspension system rested upon a support similar to the well-known mirror box used by Edelmann in his galvanometers. The cylinder to which the glass front was attached not only revolved through a large angle, thus affording a wide range, but could also be entirely lifted off of the instrument, thus exposing the mirror and making it perfectly easy to attach the suspension wire.

The aluminum wire to which the mirror was attached terminated just above the latter in a very small screw clamp and a similar clamp was fastened to the lower end of the sliding brass rod which moved in a friction-bearing at the upper end of the suspension tube. The suspension wire was firmly held by these clamps and a new one could be inserted at any time in a few seconds without disturbing any other part of the instrument.

The ingenuity of the makers also provided an accurate and delicate adjustment of the mirror about a horizontal axis lying in its plane. The needle was of aluminum and of the ordinary form. A wire extended from its lower surface to the space below the quadrants and was terminated in a short slip of mica, so that an air damper might be used if desired, or liquid damping arranged for. Wide doors on opposite sides afforded convenient access to the quadrants and the interior of the case.

The workmanship throughout was of a high character and fully up to the standard so generally maintained by the Société Genevoise.

Fig. *a* shows the instrument with the window cylinders removed.

In all of the instruments except that for photographic registration, readings were made by means of the ordinary lamp and scale method, the scale being usually drawn upon ground glass and distant about one metre from the electrometer.

Method of using the electrometer.—Three methods of charge and connection for the quadrant electrometer have been used and recommended by different authorities, each of which undoubtedly has peculiar advantages under certain conditions.

Following Sir William Thomson's classification, in two of these the charge is heterostatic, and in the third it is idiostatic.

In the first, the needle of the electrometer is maintained at a constant potential, and one pair of quadrants is connected with the earth and the other to the body whose potential is to be measured. In the second, the two pairs of quadrants are charged to the same potential, the signs being opposite, and the needle is joined to the body whose potential is to be measured.

In the third, both the needle and one set of quadrants are joined to the body under examination, while the other set of quadrants is connected with the earth.

These methods, in the order given, are frequently referred to as the method of Thomson, of Mascart, and of Joubert, and they will be so designated here.

The last, that of Joubert, is evidently not suitable for use in the study of atmospheric electricity, and it is necessary to choose between the first two.

In order to be able to state clearly the reasons for deciding in favor of the second, it may be well to state briefly some theoretical considerations, which have not always received the attention they deserve.

The general equation for the quadrant electrometer as given by Clerk Maxwell is as follows:

$$\theta = \alpha(A - B)[C - \tfrac{1}{2}(A + B)]$$

in which θ = moment of couple acting on the needle.
α = a constant depending on the instrument.
A and B = potential of quadrants.
C = potential of needle.

In the Thomson method of mounting, one quadrant is connected with the earth and its potential is zero. The equation then becomes

$$\theta = \alpha(AC - \tfrac{1}{2}A^2)$$

and, α and C being constant, it represents a common parabola.

If a curve be constructed from observations, the deflections being platted as abscissas and the potentials of the quadrant as ordinates, as has been done from actual experiments, the points determined by observation being indicated on the curve, it will be seen that the assumption ordinarily made, namely, that the deflections are proportional to the potentials, is only approximately correct through a relatively small range. For a short distance on either side of the origin the curve is approximately a straight line, but it is worthy of note that the

inclination to the axis is different on the two sides, and that it is therefore important that care should be taken in comparing potentials to see that the signs of the charges on the needle and on the quadrant are similarly related to each other in both cases. If C, the potential of the needle, is very large compared with A, and this is generally recommended, the error in assuming that a straight line will represent the observations is very small.

Thus if C = 5,000 and A is not greater than 100, the error will not exceed 1 per cent., and in general, as the equation easily shows, if C is the potential of the needle and ε is the fractional error permissible, the maximum potential which can be measured is $A = 2\varepsilon C$.

In the Mascart method of mounting, A and B are equal, constant and of opposite sign. The general equation then reduces to this:

$$\theta = 2\alpha AC.$$

Here θ and C are the variables and the equation is that of a straight line; in other words, the deflections will now be proportional to the potential of the needle.

Gouy, in the Journal de Physique for March, 1888, shows that the general expression for the moment of the couple acting on the needle of the quadrant electrometer, in the case of a symmetrical charge, as given by Maxwell, is incomplete, in that it lacks a term to express the effect of what he terms the "electric directing couple."

The existence of this couple he establishes by vibrating the needle uncharged, first when the quadrants are also at zero potential and then with increasing differences of potential between them. In the case cited by him the period of the needle was 13 seconds with the quadrants uncharged and this was reduced to 1.45 seconds when the difference of their potential was 1,400 volts. The displacement of the needle from its zero brings into existence a force opposing this displacement, which force, according to the experiments of Gouy is proportional to the square of the differences of potential between the two sets of quadrants.

Including the term expressing this effect and also the suspension couple, supposed in this case to be torsional, the completed equation would stand as follows:

$$\theta = \alpha(A-B)[C-\tfrac{1}{2}(A+B)]-\beta(A-B)\delta^2-\varsigma\delta.$$

in which, in addition to the terms already defined,

δ = deflection.

ς = moment of suspension couple for unit deflection.

β = moment of electric couple for unit deflection.

Supposing as before, A = B, this becomes

$$\theta = 2\alpha AC-(4\beta A^2+\varsigma)\delta = 0$$

when the needle is at rest.

Hence,

$$\delta = \frac{2\alpha AC}{4\beta A^2+\varsigma}.$$

Here δ and C are the variables and the equation is again that of a straight line.

It may be worth while to point out one of the results of the existence of this "electric directing couple," which is indicated by Gouy in the paper referred to above and which further illustrates the advantage of this method of mounting the electrometer.

It is clear that the sensibility of the electrometer will not continually increase with the increasing charge on the quadrants, for of the two opposing couples, one increases simply as the difference of potential of the quadrants and the other as the square of this difference. The curve of sensibility will therefore have a maximum point.

An examination of the equation shows that the rapidity with which this curve falls off on either side of the maximum point depends, other things being equal, on the magnitude of the suspension couple, being less as this couple is greater.

It follows from this interesting fact that a stiff suspension affords a relatively long range about the point of maximum sensitiveness throughout which it is sensibly the same; that is to say,

considerable variations may be made in the charge upon the quadrants without altering the deflection of the needle for unit potential.

As it is next to impossible to maintain a constant quadrant charge by means of ordinary batteries, it is important to take advantage of this fact by using wire suspensions and a greater number of cells.

The Mascart method of mounting also possesses advantages in the matter of insulation. In studying atmospheric electricity, where generally although the potential may be high the quantity is small, it is essential that that part of the electrometer which is in connection with the collector should be well insulated.

The quadrants are usually supported by short glass stems, while the length of the needle suspension may be anything desired, and it is thus easier to secure high insulation of the needle than of the quadrants.

For these reasons the Mascart method was used in all of the work, except during some of the earlier experiments at Cambridge, in which the Thomson plan was followed.

Charging batteries.—In nearly all cases a water battery was used for charging the quadrants and generally the form adopted by Mascart, consisting of small porcelain cups imbedded in paraffine, filled with pure water and joined in series by metallic couples consisting of small strips of copper and zinc soldered together and bent into a proper form. These batteries are by no means constant in their potentials, and require considerable attention on account of loss by evaporation, and danger from dust, which often contains foreign matter enough to produce decided changes in the electromotive force of the cells, and as this change is not always the same throughout, the battery, the middle point of which is connected with the earth, is thrown out of balance so that the charges on the quadrants are no longer equal.

A number of experiments were made at Cambridge, under the direction of Professor Trowbridge, with the well-known Beetz battery, prepared by inserting copper and zinc wires in the two arms of a bent glass tube which had been filled on the one side with a paste made of plaster of Paris and a copper sulphate solution, and on the other with a similar paste of zinc sulphate. The ends of the tube are sealed with paraffine, after the setting of the plaster takes place. A considerable number of these cells were prepared at Cambridge and they appeared to be very satisfactory as to constancy, even after more than a year after their construction.

Certain mechanical difficulties prevented their general use, the principal being their somewhat fragile nature, in virtue of which they were liable to accidents resulting in damage, neither the nature nor the location of which could be readily determined.

The ordinary water batteries, with all of their parts exposed and easily supplied, were better suited for use at the various stations.

They were in boxes containing fifty cells each, that number being generally sufficient and often more than sufficient for producing the necessary charge in the quadrants. The middle point of the battery was connected with the earth and the zinc and copper terminals to the two sets of quadrants.

As already stated, it is very difficult to secure an exact equality of potential on both sides of the earth connection, owing to inequality in the cells. On this point M. Gouy, in the paper already quoted, makes the very important suggestion that sensible equality may be secured by joining the poles of the charging battery by an extremely high resistance, the middle point of which is connected with the earth, the battery being otherwise entirely insulated. This method would eliminate inequality of the cells and is to be strongly recommended where work of high precision is desired.

For purposes of calibration reference was usually had to some standard battery at hand. In the experimental work in the laboratory at Washington a collection of nearly a hundred cells of the ordinary gravity battery was used, the potential of which was always known by means of one of Sir William Thomson's gravity volt-meters, which was joined in circuit with the battery and a very high resistance. A very convenient battery for calibration, especially where a large number of cells is required, is the water battery devised by Professor Rowland and described by him in the Philosophical Magazine for March, 1887. It is easily prepared, and a large number of cells occupy a very small space.

COLLECTORS.

The water-dropping collector, as devised by Sir William Thomson, is the only one which has been very generally used in observations of atmospheric electricity.

In the observations of Wislizenus in this country and those of several European observers, notably Palmieri, other forms have been made use of, but the many advantages of the water dropper in the way of convenience and especially for continuous registration have led to its well nigh universal adoption.

In the course of this investigation, experiments were made with the burning match or flame collector and with one or two other forms which will be shortly described. The water-dropping collector was in general use at the stations, however, the form usually adopted being that of a cylindrical vessel of galvanized iron large enough to contain sufficient water for a run of 24 hours.

This vessel was mounted on three large insulators of the Mascart pattern, and to the lower part of the cylinder was attached a long brass tube about 1 centimetre in diameter and 2 or 3 metres in length. The outer end of this tube was provided with a close-fitting cap, in which was a small orifice through which the stream of water flowed, breaking into drops at a distance of 10 to 20 centimetres. To prevent the bending or breaking of the tube, a wire attached to the upper rim of the iron vessel was fastened to it near its outer end. At nearly all of the stations arrangements existed for filling the collector at any time by turning a stopcock. At Cornell University, where in several respects the arrangements were more perfect than elsewhere, the collector was mounted on a table running on casters so that it could readily be moved back and forth, the whole being completely within the room whenever desirable, except at the time of observation. One of the objections to the water-dropping collector is its liability to freeze in extremely cold weather, and in some cases the photographic registration was interrupted in this way. The station at Ithaca was one of the most exposed, but trouble from freezing was avoided in the manner described.

At other stations when the collector could not easily be moved, the difficulty could generally be overcome by removing the tube and warming it just previous to an observation.

At Baltimore Sergt. Park Morrill designed, under the direction of Professor Rowland, a mechanical collector by which it was hoped that the objections to the water dropper might be avoided and all exposures made strictly comparable with each other.

Something of the same kind had also been attempted at Cambridge.

To serve for photographic or other continuous registration it is necessary that the collector shall be continuous in its operation and sufficiently "quick" in its action to enable it to follow close upon the electrical variations, which are often quite rapid. In this respect the water-dropping type offers great advantages.

It was finally determined to construct a mechanical collector, following the designs of Rowland and Morrill, but unfortunately it was not completed until the whole work was just about to close, so that nothing very definite can be said as to its performance.

The principal parts of the machine are shown in Fig. 1, and a brief description of it is as follows:

An insulated conductor, which will be called the *inductor*, is fixed in position and continuously covered and uncovered by a metallic cap at the end of a revolving arm moved by clockwork, the cap being always connected with the earth. Simultaneously the inductor is alternately connected with the earth and to an electrometer, the earth connection being made either when the cap covers it or when free, and the connection to the electrometer being made at the opposite phase of the action. If the earth connection be made when the inductor is covered by the earth cap, it is thereby freed from charge and, when uncovered, assumes the potential of the air.

If the earth connection be made when the inductor is freely exposed, it is charged by induction and, upon being insulated and covered by the earth cap, it assumes an equal potential of opposite sign.

The electrometer reaches its true readings by successive approximations with each succeeding contact, the rapidity of its action depending on the relative capacities of the inductor and the electrometer.

Fig. 1 shows the instrument and Fig. 2 the same with the outer cover removed. The inductor is at *a* and the revolving arms and earth caps at *b*. In Fig. 2 the glass stem insulating and supporting the inductor is seen at *c* and the close chamber closed by glass sides at *d*, within which the contacts are made and which contains a vessel of sulphuric acid for drying. Contact between the inductor and the contact wheel is maintained by the wire *e*.

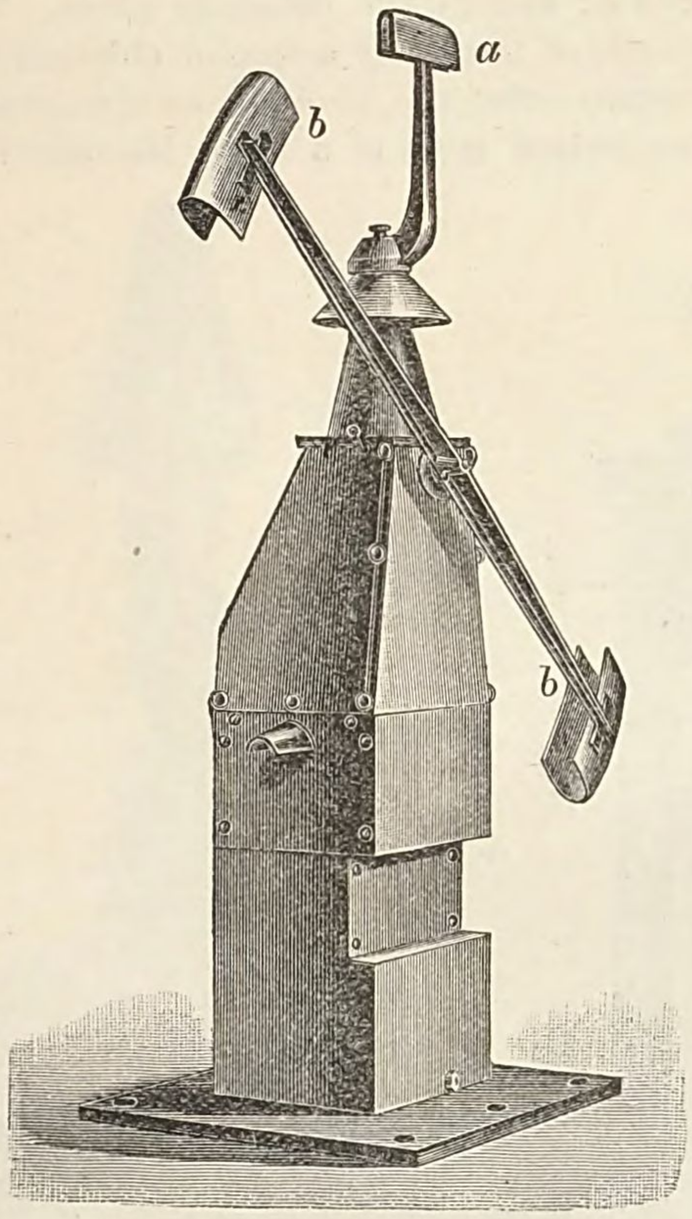


Fig. 1.

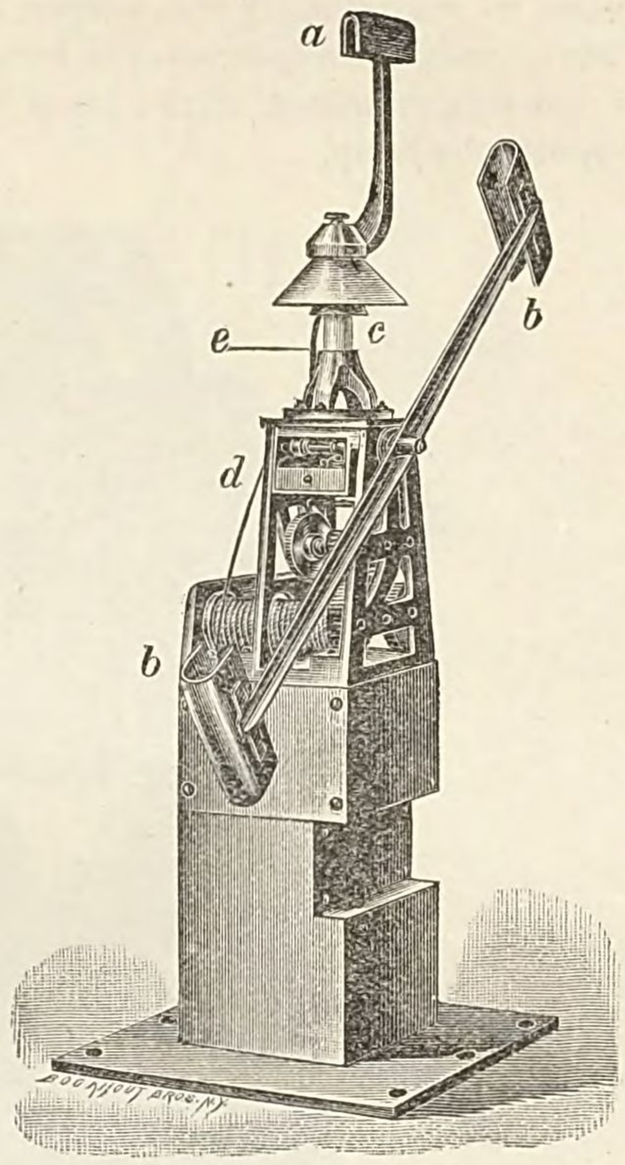


Fig. 2.

In Fig. 3 the details of the instrument are shown on a large scale. The lower two-thirds of the cut shows the drums and wheel work by which the axle shown on the left, is driven.

The sides of the acid chamber have been removed showing the leaden vessel *g* containing sulphuric acid.

The wheel *h*, driven by the revolving axle, supports by glass rods an insulated ring and contact pin. The contact spring *i* makes the ground connection through the pin, the ring being constantly in contact with the wire *e*. The connection with the electrometer is made at the opposite side of the contact ring from *i*, by a spring not shown, connected to a binding post from which a wire is carried to the electrometer. The contact wheel *h* revolves twice as fast as the axle so as to go through the two phases of its action for each of the two earth caps carried by the revolving arms *b*. The socket, the base of which is seen at *d*, supports the inductor. If the fixed inductor, which is exposed to inductive action, were completely covered by the earth cap, the potential measured would be that of the air at the same height. But, in addition to the inductor proper there is a supporting rod and an umbrella to protect from rain which can not be covered by the cap and, in consequence the potential is lower than would be obtained by the water dropper at the same height.

The inductor being only partially freed from charge when covered by the earth cap and connected to the earth, for absolute values the results obtained would require the introduction of a correction factor. The electric action of the collector is fully as rapid as that of the water dropper and it gives a curve of the same character but with smaller values.

Sergeant Morrill also experimented upon a flame collector, especially with a view to overcome one of the principal objections to that form, its liability to be extinguished by the wind, rain, etc. He was quite successful in designing a form which during the short period of its use, before the termination of the work, gave very satisfactory results.

The principle upon which blowing out was prevented was that the lamp must be so constructed that the wind would exert equal pressures on the feed air and on the escaping gases. This was accomplished by surrounding the proper chimney (made of metal) by a second chimney, causing the feed air to pass down between the two, and by surmounting the whole by an open cone. Gas was used and was admitted to the lamp through the hollow stem of a large Mascart insulator which supports the lamp.

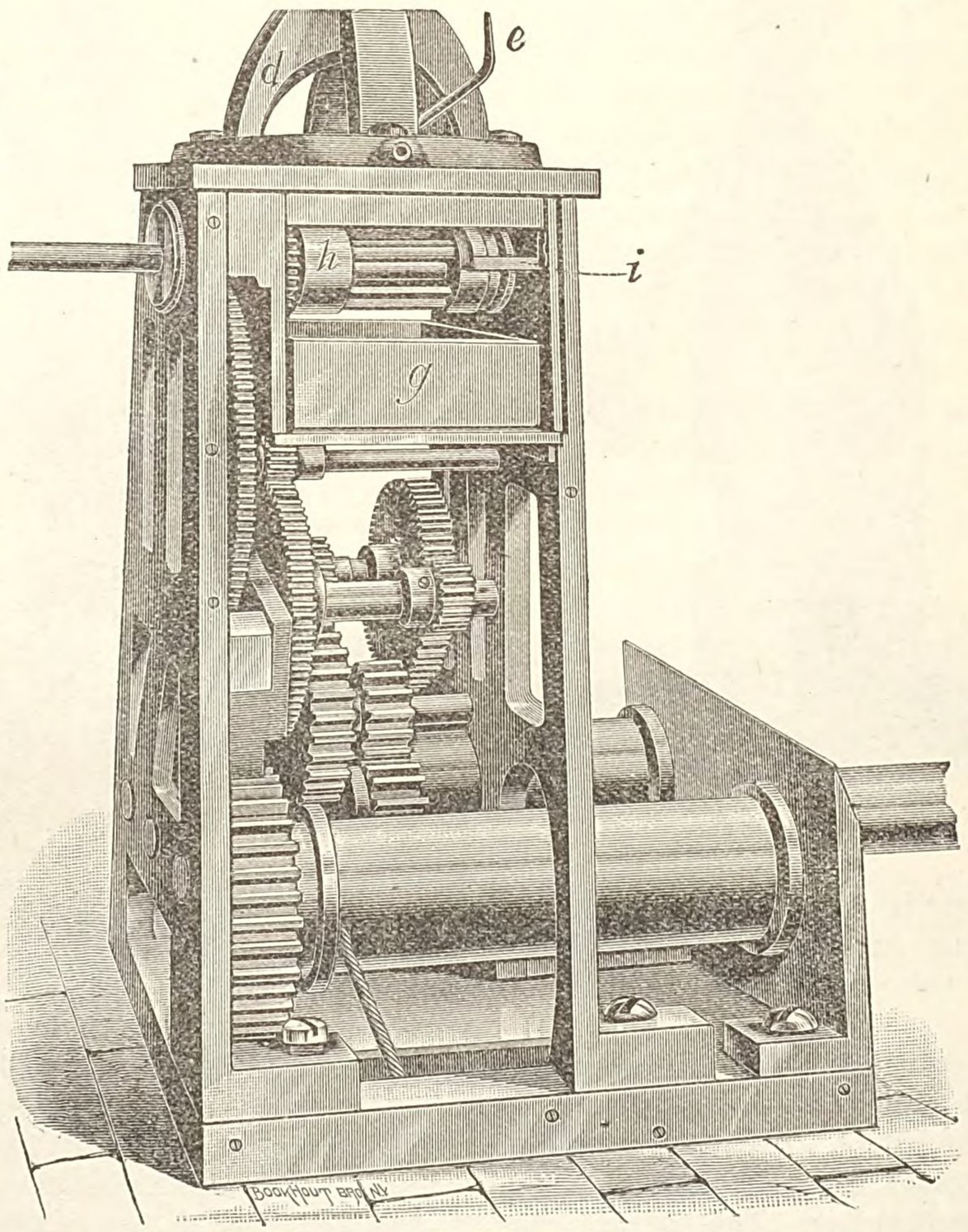


FIG. 3.

Fig. 4 shows the collector complete. The insulator, supporting the apparatus, rests on air tight rubber packing, and is held firmly by metallic straps. The tube shown in the foreground conducts the gas to the base of the insulator.

Fig. 5 is a sectional drawing of the same. A is the baseboard to which the insulator B is attached by a collar and the straps C. The gas enters at the pipe D, passing by the hollow stem E to the argand burner F. G and G_1 are the inner and outer chimneys, respectively. H is a solid collar around the stem E to support the outer chimney G_1. The cone J is supported by three brackets, K. L is an umbrella to protect the insulator from rain. The course of the feed air and of the products of combustion is shown by arrows.

Some difficulty in the use of this collector was found to be due to variations in pressure of the

gas supply, and this was obviated by the addition of a governor, made in the manner shown in the sectional drawing, Fig. 6. Gas enters through the stopcock B, and passes to the collector by the pipe C. A burner is first selected which will burn freely enough at the minimum pressure or less. Water is introduced into the vessel A to such a height that its elevation above the bottom of the pipe C gives this pressure, that is, the proper burning pressure, which may be less than the

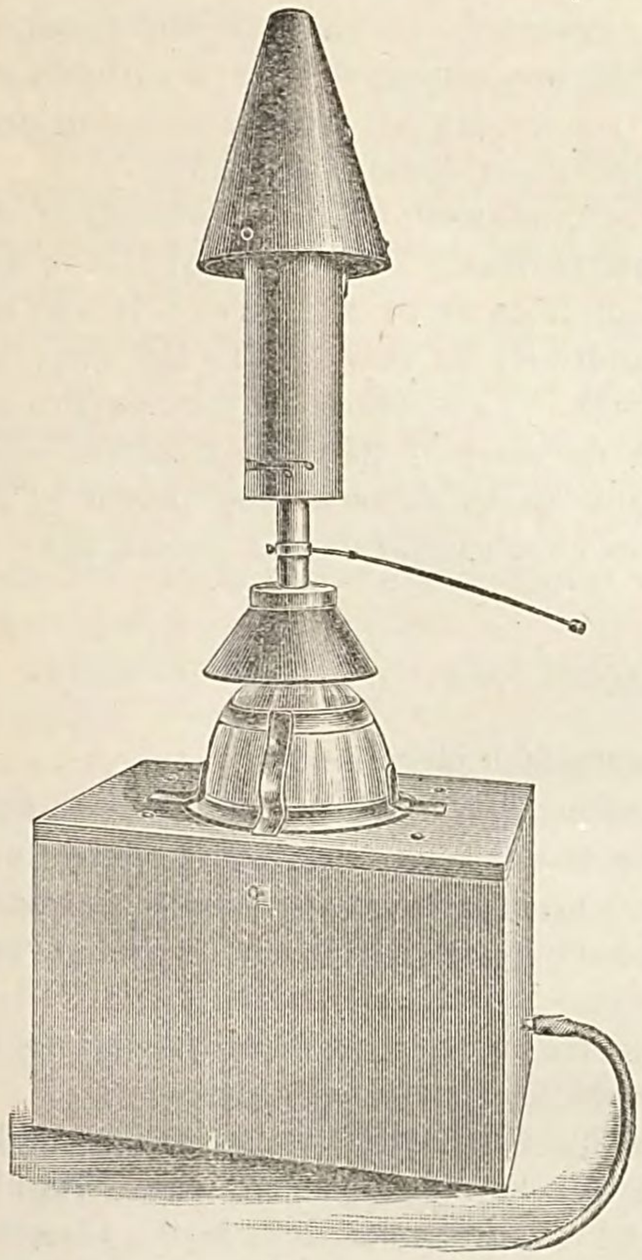


FIG. 4.

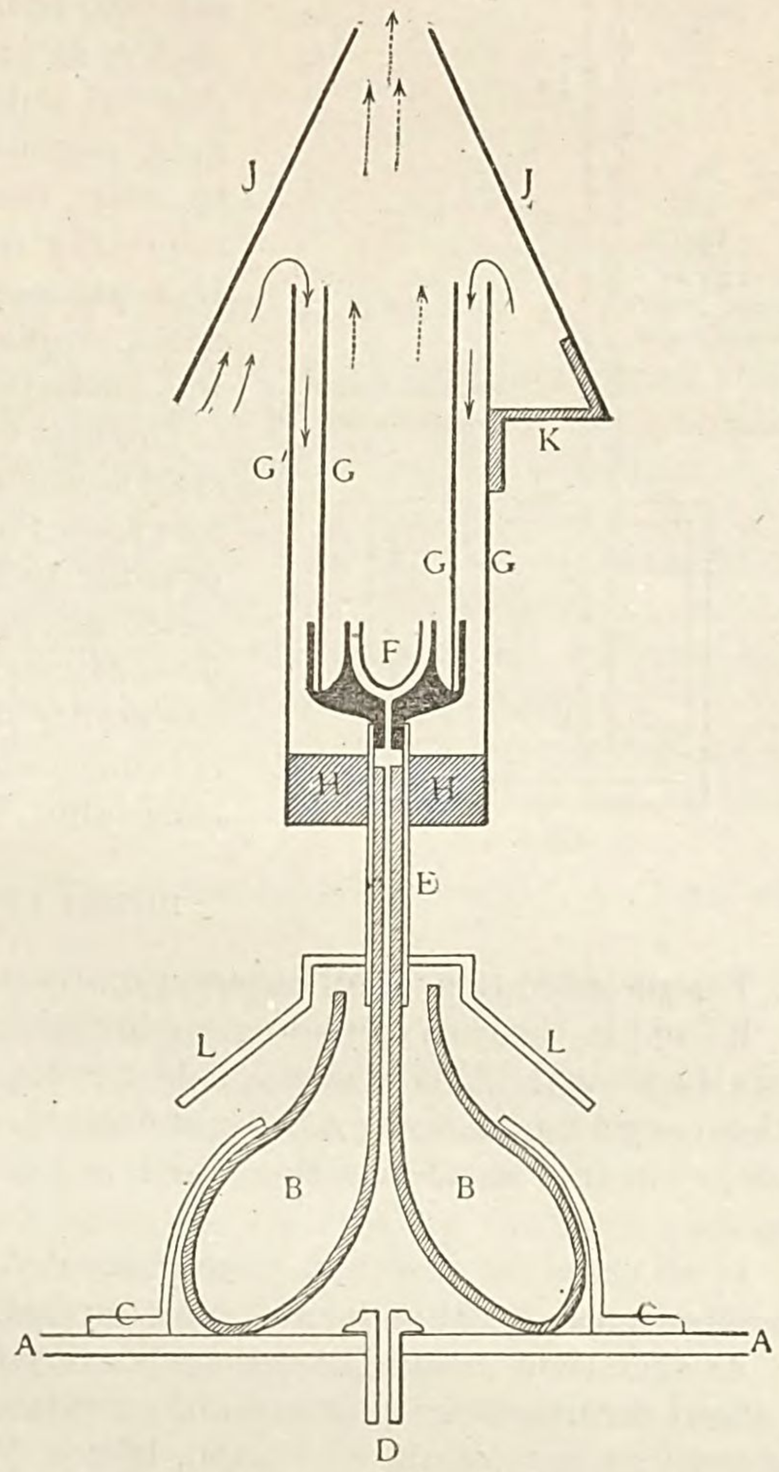


FIG. 5.

minimum of supply, but not more. If the adjustment be to less than the minimum pressure occurring, the stopcock B is turned partly off, so that, at the time of minimum pressure, the gas just forces the water to the bottom of the pipe C. When the pressure rises, gas escapes from the bottom of the pipe C, and thence to the air by the pipe D, while the pressure to the collector remains the same.

It is evident that by the use of either of these collectors, well-defined exposures may be obtained. The mechanical collector is nearly symmetrical about a vertical axis, and the lamp collector is entirely so. If such a collector be placed in the center of a circular, plane, metallic surface, whose radius is large, compared with the elevation above it of the inductor of the mechanical collector or the apex of the lamp collector, the potential determined would be proportional to the elevation of such collecting point and results at different stations ought to be directly comparable.

EXPOSURES.

The ideal exposure for a collector in the study of atmospheric electricity would be on a large, flat plain, free from buildings, trees, or other elevated points.

Indeed, it would not differ greatly from the ideal exposure for other meterological instruments, thermometers, rain gauges, wind vanes, anemometers, etc. Such exposure, however, is practically unattainable, and in the present instance it was necessary to accept whatever arrangements were available at the several points where stations were located.

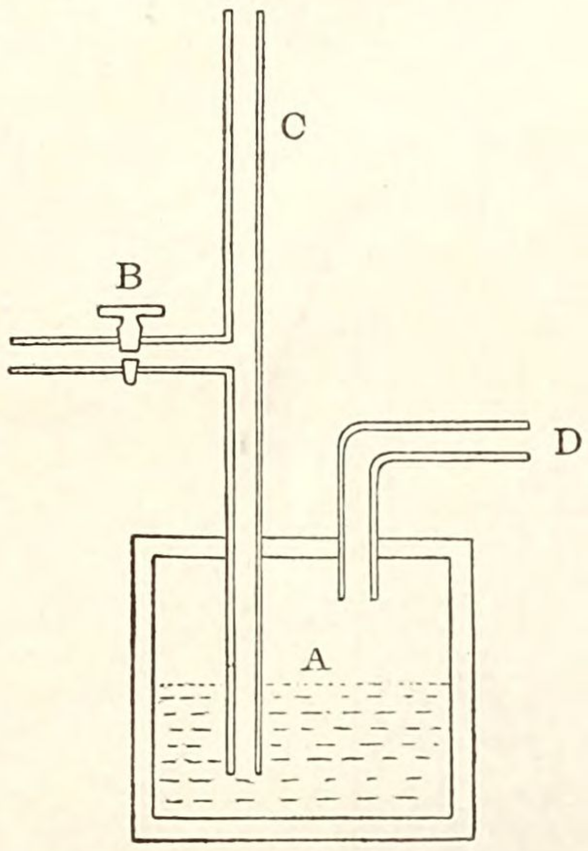


FIG. 6.

The electrometer, charging batteries, etc., were generally established in some room temporarily vacant, or, in the absence of such, in an unused part of an occupied room. Where this room was near the top of the building and was lighted by a window opening upon a clear space, not hemmed in or in any way surrounded by walls, the collector was mounted near the window, the tube projecting from the same, generally as far as 1½ to 2 metres. In other cases the collector was mounted near a suitably exposed window away from the observing room, and connection was made by means of Mascart suspension insulators.

The first arrangement was preferred, as the insulation of the system was then much more perfect. The height of the collectors from the ground varied from 10 to 20 metres. It was not possible to secure any uniformity in this, nor in the direction (orientation) of the exposures. As a matter of fact, experience demonstrated that *for the purposes of this investigation* such uniformity was by no means essential, as will be shown in the consideration of simultaneous observations at points near to each other.

HOURS OF OBSERVATION.

The recorded time of all observations is that of the seventy-fifth meridian.

Except in the case of photographic registration, observations were made at four or five stated hours each day. This was the rule for days on which the indications were fairly steady and without rapid fluctuation. At all stations, observations of much greater frequency were occasionally made, even in "steady weather," and in some instances hourly records were made for several months.

In all cases the observers were instructed to increase the frequency of their observations on the appearance of a thunder storm or any indication of unusual electrical conditions.

At such times readings were made every few seconds, so that the records are quite as valuable as those furnished by photographic registration. During the last year of the work, regular observations were made at Boston, Ithaca, Washington, and Terre Haute at 9 a. m., 11 a. m., 1 p. m., 3 p. m., and 5 p. m., with additions of series of observations of greater frequency whenever the conditions seemed to make it desirable.

The spot of light, the position of which on the screen indicated the potential of the collector, was rarely absolutely at rest for any length of time, and the number recorded for any regular observation was always the mean of several readings made every minute, both before and after the stated hour. A calibration of the electrometer was made generally once every day so that fluctuations in the potential of the charging battery were accounted for.

Usually not more than fifty cells were used in charging the quadrants, and when the indications were unusually strong, so as to approach the limits of the scale, this number was reduced so that readings were still possible. On many occasions, however, the limit of the instrument was reached, and the spot of light would leave the scale entirely.

The strength of the suspension wire was generally such that records were possible up to near the "sparking" limit. The highest potential measurable at most of the stations was approximately 5,000 volts, and in some instances this would be exceeded during a whole day, sparks passing almost continuously between the needle and the electrometer quadrants.

At Terre Haute, one of Thomson's electrostatic voltmeters, which had a high maximum limit was used at such times. The insulation in this instrument is excellent, and its performance was very satisfactory.

In continuous registration the calibration constant was marked on the photograph sheet. The time registration, as it existed in the instrument when first received, was found to be defective, but modifications were made by Morrill sending the time record satisfactorily.

To reduce the time records to local mean time, the following approximate corrections must be applied.

	Minutes.
Boston	+16
Ithaca	— 6
Baltimore	— 6
Washington	— 8
Columbus	—32
Terre Haute	—50

PRELIMINARY AND SIMULTANEOUS OBSERVATIONS.

In the summer of 1885 it became possible to begin, at the office of the Chief Signal Officer in Washington, a series of experiments bearing on the question of exposure for the purpose of determining to what extent it would be necessary to insist on similarity of arrangement at the different stations.

The circumstances under which these experiments were made were extremely unfavorable.

The working laboratory was in the basement of a building, No. 1704 G street, northwest. The only available open space was a small area on one side of the rear of this room, about 8 metres wide by 12 long, entirely surrounded by brick walls up to a height of 18 to 20 metres.

The roof of one of these buildings could be used, and in order to obtain a more elevated and more free exposure for experimental purposes, a mast was erected on this roof, reaching a height above it of about 15 metres.

At its top was a projecting beam somewhat less than a metre long, to which pulleys were attached.

Over these pulleys small brass chains ran, reaching the ground about 30 metres below, and by means of which two collectors were raised and lowered.

These collectors were of the water-dropping type, consisting of small metallic vessels, with dropping tubes about 30 centimetres in length. They were attached to the chains by insulators and connected to the electrometer below by means of fine wire. It was difficult to insure a very perfect insulation of the system, but that of the two collectors was sensibly the same and sufficiently good for the purpose.

Two electrometers were carefully adjusted until they had practically the same constant, giving nearly identically the same indications when attached to the same collector.

With this arrangement a number of experiments were made to determine the degree of agreement between the indications of two collectors, as nearly alike as possible, and exposed as nearly in the same way as possible.

It was at once discovered that considerable differences in the potential indicated by the two collectors existed. It was found, however, that so long as the collectors remained at a given height, the difference between their indications was practically constant, so that when their curves were drawn they agreed almost exactly in form. As was to be expected, the differences increased with the elevation of the collectors.

The collectors were interchanged in their position as to the mast, and in their electrometer connections. It was found that the innermost collector, that nearest the mast, always gave the lower potential.

The conclusion drawn from these experiments was that while it would be very difficult under ordinary circumstances to secure two exposures which should indicate the same absolute potentials, there was little doubt but that two collectors placed very near to each other would show similar potential variations.

In the spring of 1886 more electrometers were available, and simultaneous observations were resumed with increased distances between the collectors. An instrument was established in what was known as the "instrument room," the exposure being on the north side of a large lattice-work shelter, the height of the nozzle being about 14 metres from the ground, and the stream of water was broken at a point a little less than 2 metres from the lattice work.

The collector was a large cylindrical metallic vessel mounted as already described. This station was about 100 metres distant from the mast at the laboratory, from which the second collector was suspended at a height of 3 metres from the roof on which it was located.

It will be seen that these exposures were, in some respects, quite different, yet generally their potential curves were quite similar. Figs. 7 and 8 show two examples of simultaneous observations at these two points, covering a half hour each day, during which readings were made with such frequency as to be practically equivalent to a continuous record.

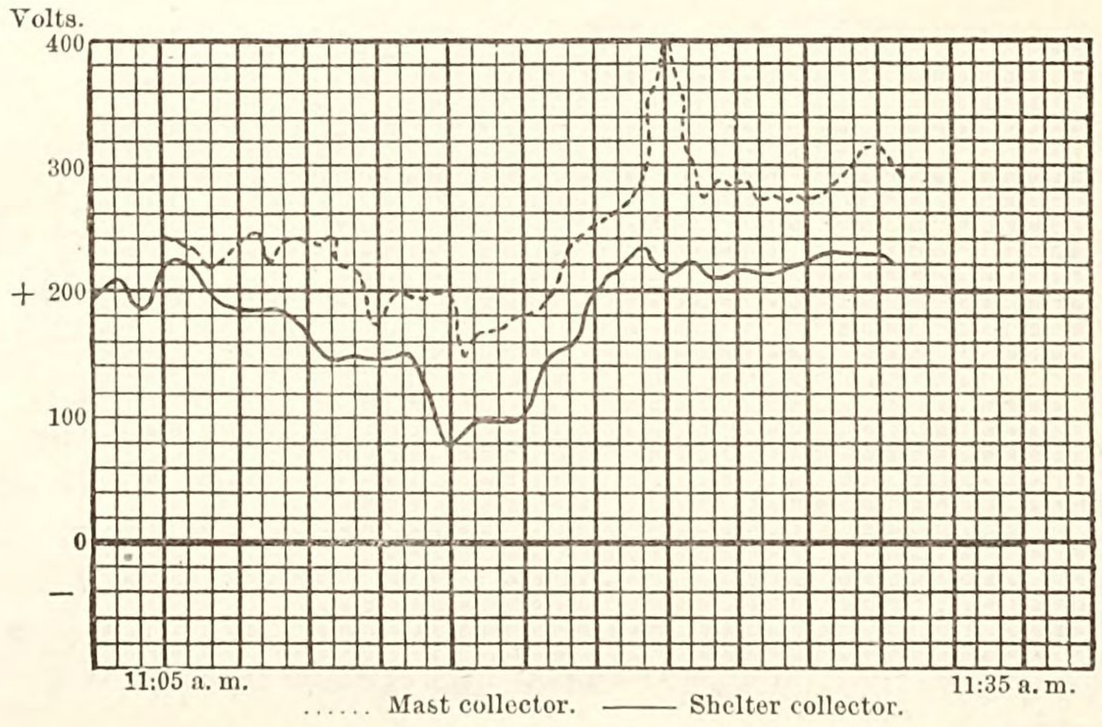


FIG. 7.—Comparison of exposures, Washington, D. C., May 5, 1886.

They were first printed in the Monthly Weather Review for April, 1886, and are selected as good illustrations of movements on both sides of the line of zero potential. The curves showing positive readings are not in as close agreement as those showing negative, and in both cases it

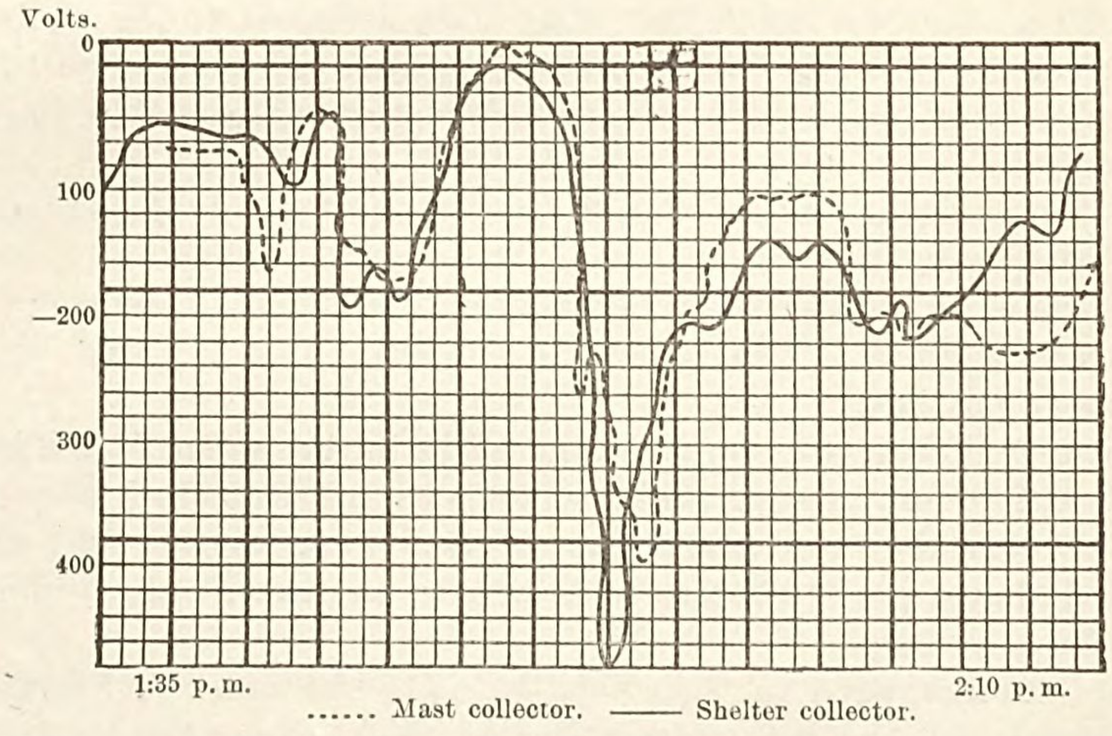


FIG. 8.—Comparison of exposures, Washington, D. C., May 5, 1886.

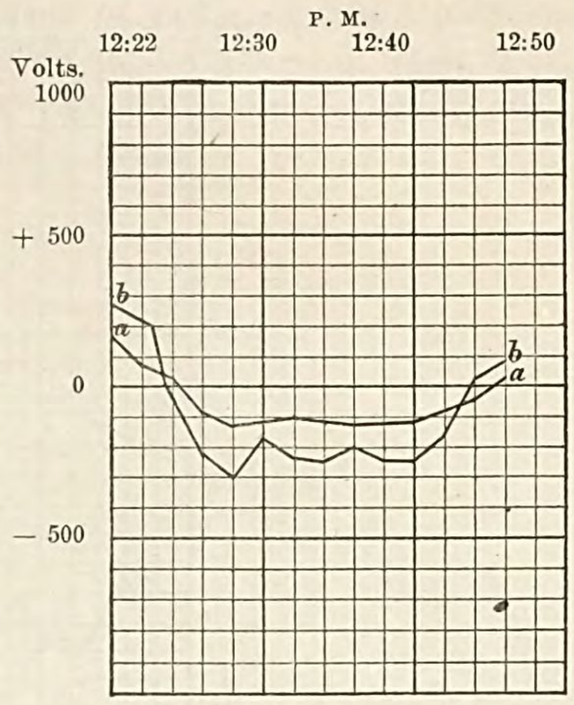
will be observed that while the general movements at the two stations were very similar, there were at times considerable differences in rate and direction of changes of potential. These differences are much greater than in the cases of two collectors only a metre apart, and it is clear that even when two points are not further separated than 100 metres, indications of variations in potential may be quite dissimilar.

In August, 1888, similar comparisons were made by Morrill at Boston, using his flame collectors, one of which was exposed on a balcony about 15 metres above the ground and another on the roof of the same building 7 or 8 metres above the first. During these observations the weather

was very warm, sky overcast with cumulo-stratus clouds, light northwest winds. Shortly after noon a shower appeared in the west and passed around to the south, not reaching the station. Figs. 9 and 10 show the potential curves drawn from observations made every 2 minutes at each collector.

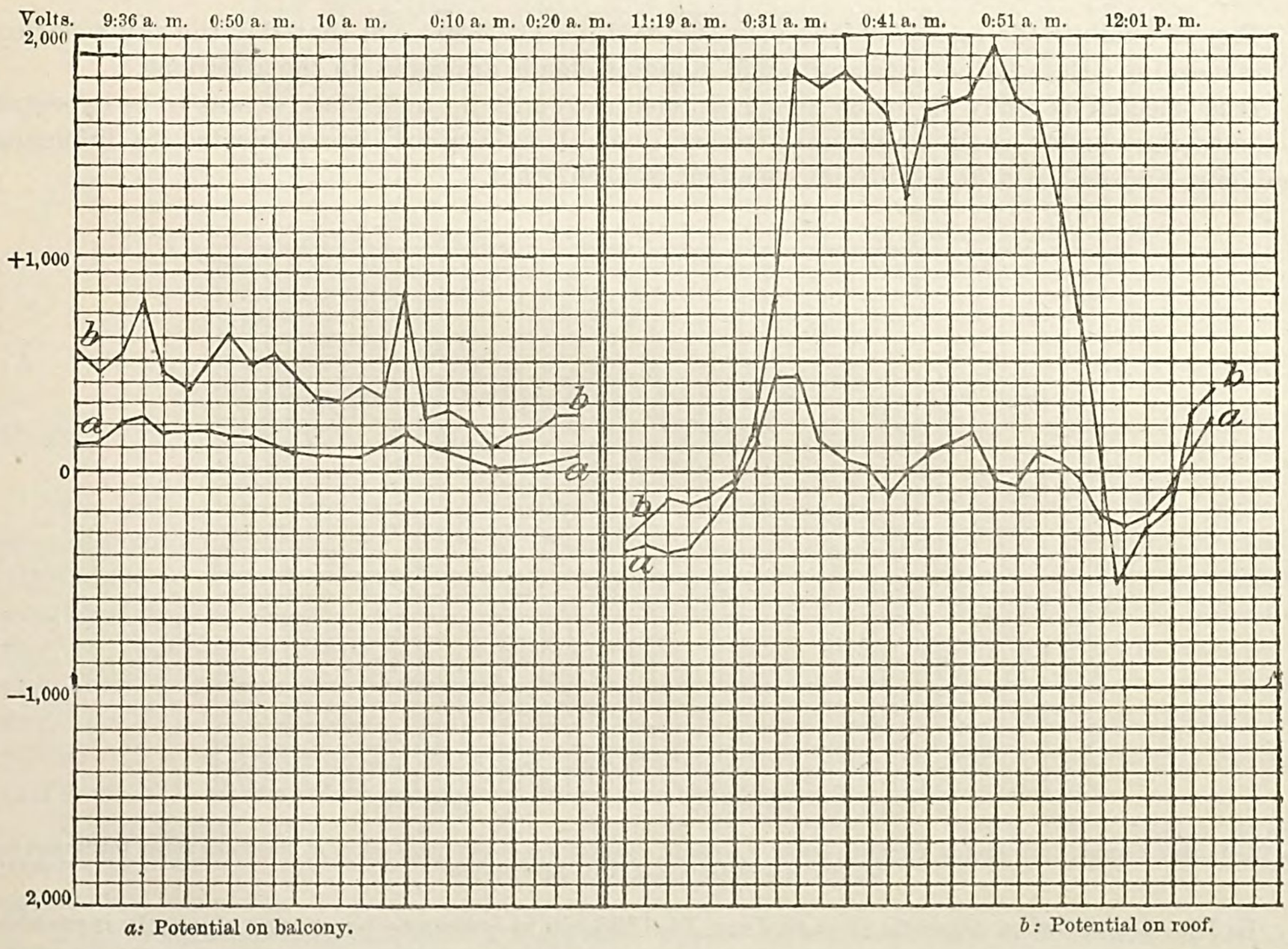
In all cases the roof collector shows the greatest range of moment, that exposure being undoubtedly much more free than the other; but the general character of the changes is nearly the same in both.

The next step in the matter of comparative observations was to increase very considerably the distance between the two stations. Through the courtesy of the late Professor Baird, then Secretary of the Smithsonian Institution, an electrometer with accessory apparatus was mounted in the central tower of that building, the exposure being from a north window, at a height of about 17 metres. The other station was that of the instrument room at the Signal Office already referred to, the distance between the two being approximately 1 mile. During several days simultaneous observations were maintained at these two points and some of the results are shown in Figs. 11 and 12. In all cases the observations were not less frequent than once in 5 minutes, and when the movements of the needle were rapid they were made as often as once a minute. It would be impossible to plot all of the more minute



a: Potential on balcony. *b*: Potential on roof.

FIG. 9.—Comparison of exposures, Boston, Mass., August 17, 1888.



a: Potential on balcony. *b*: Potential on roof.

FIG. 10.—Comparison of exposures, Boston, Mass., August 17, 1888.

movements without producing confusion in the diagram, but the more important changes are correctly represented.

Fig. 11 shows the potential variation during several hours of June 4, 1886, a day on which the weather was fair with gentle variable winds. Considerable difference in both character and magnitude of variation in potential are indicated.

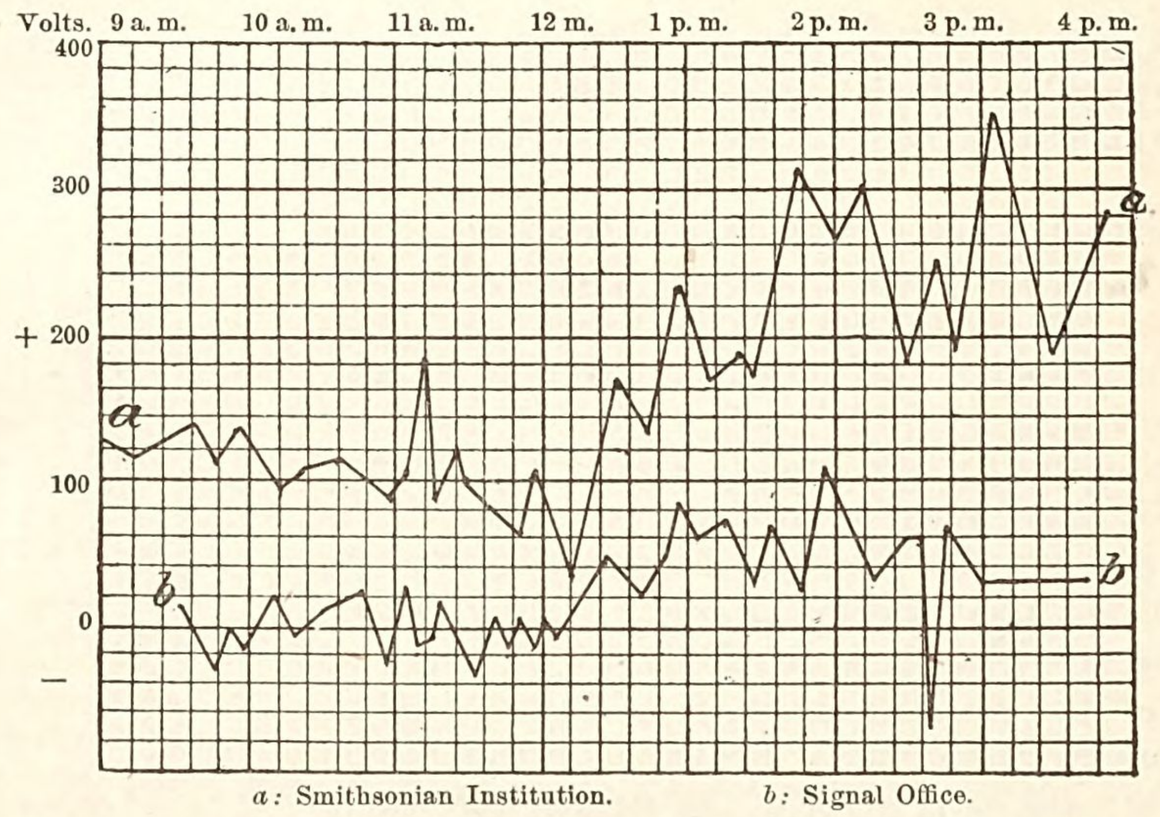


FIG. 11.—Curves showing the variations in potential during a series of simultaneous observations taken at the Smithsonian Institution and Signal Office, Washington, D. C., June 4, 1886. Fair weather with gentle, variable winds.

Fig. 12 exhibits the results of observations on June 11, 1886. On that day the sky was clear in the morning; the weather was warm and cumulus clouds appeared in the afternoon.

It is selected as a day on which no special electrical activity took place or was to be expected. It shows that under such conditions, two stations, 1 mile apart, are subjected to influences producing limited variations quite independent of each other.

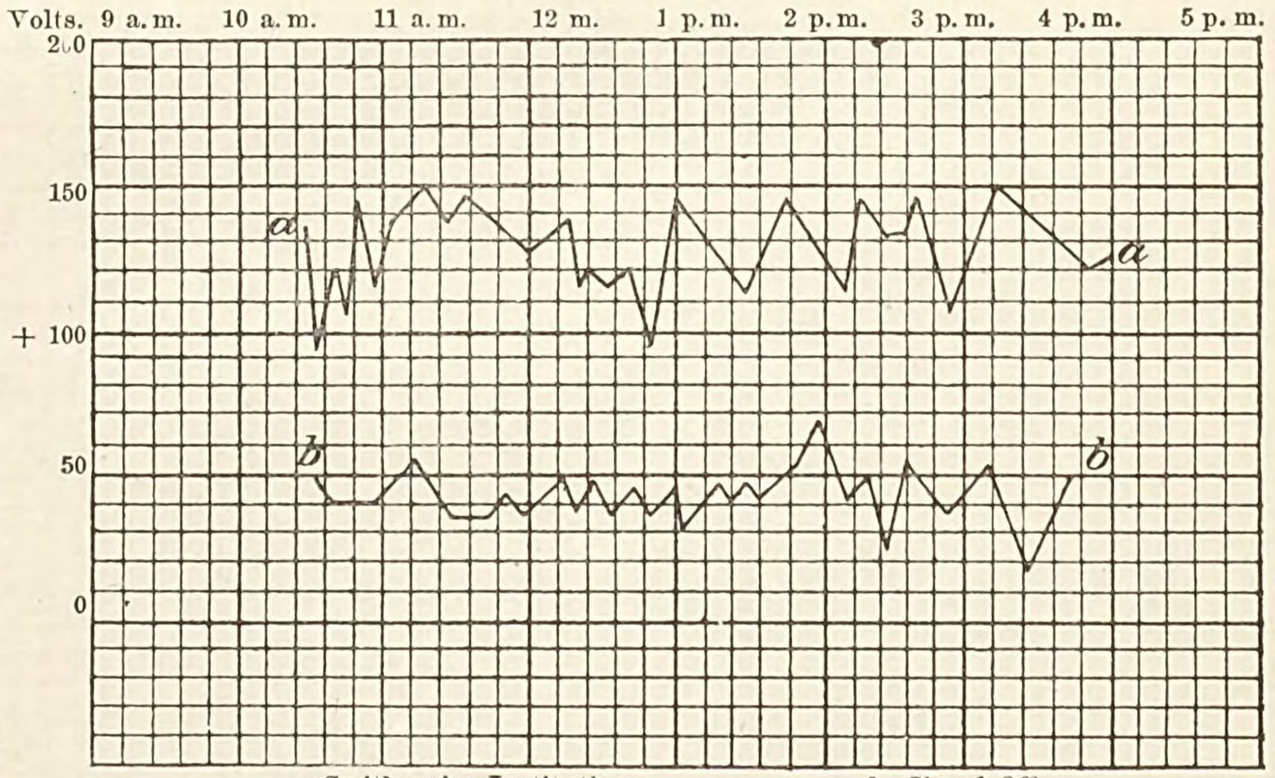


FIG. 12.—Curves showing variations of potential during a series of simultaneous observations taken at the Smithsonian Institution and Signal Office, Washington, D. C., June 11, 1886.

In Fig. 13, showing observations on June 14, 1886, there is seen to be at once a greatly increased range of disturbance and a strong resemblance in the extent and character of the movement of the needles at the two stations. That day was sultry and rainy; a thunder storm passed over the city between 1 p. m. and 4 p. m. and light rain fell at intervals between these hours. The line *a*, representing potentials at the Smithsonian Institution, shows a strong movement of the needle at 4 p. m. and for a time after that hour which the needle at the Signal Office does not seem to have

followed. In other respects the fluctuations are very similar, and it is easy to see that the prevailing disturbance was sufficiently extensive to influence both stations. These diagrams fairly represent a number of sets of observations simultaneously recorded at these two points.

The Washington Monument, which was completed in the winter of 1885, offered a point of exposure in the vicinity of the two already made use of, and through the kindness of Gen. T. L. Casey, Chief of Engineers, U. S. Army, opportunity was afforded for the establishment of a station on its summit, or rather at the base of the pyramid which completes the shaft.

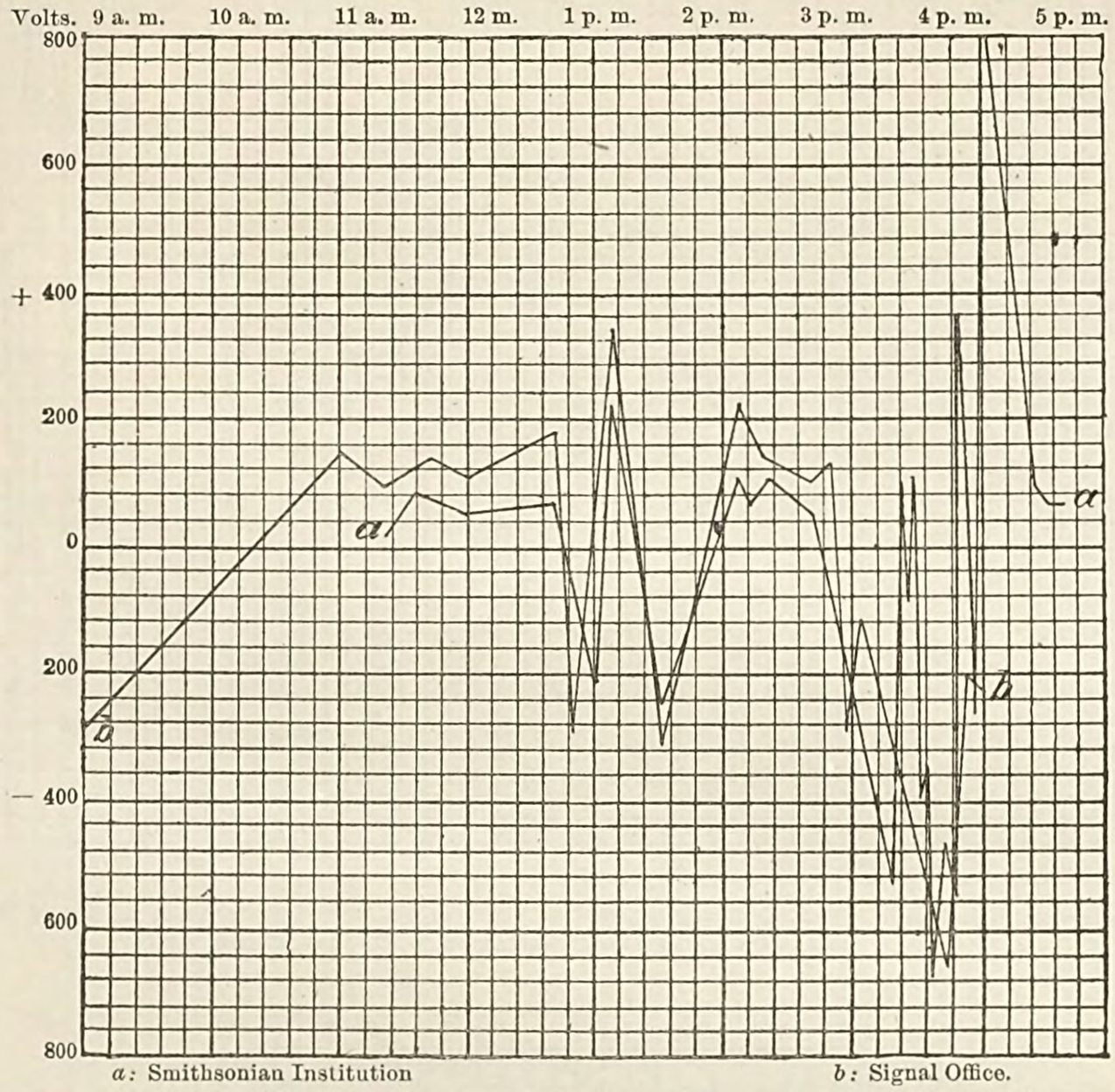


FIG. 13.—Curves showing variations of potential during a series of simultaneous observations taken at the Smithonian Institution and the Signal Office, Washington, D. C., on June 14, 1886.

The tube of the collector was projected from one of the south windows, its height above the ground being about 155 metres (508 feet) and its distance from the Signal Office about 1,000 metres (three-fifths of a mile). Several sets of simultaneous observations, often extending through the whole 24 hours of the day, were made at these two stations, readings being made every 5 minutes. Fig. 14 shows the results for June 27, 1886. The weather conditions during this period were about as follows: Clear weather, with northwest wind, from midnight to 10 a. m.; cloudy from 11 a. m. to 3 p. m.; fair, with southwest wind, from 3 to 4:15 p. m.; light sprinkling rain from 4:19 to 4:25 p. m. and from 5:10 to 5:20 p. m.; cloudy, with west wind, from 5:50 to 10:10 p. m.; light rain from 10:12 p. m. to midnight.

The diagram shows a good deal of activity throughout the whole day, and a general resemblance between the indications at the two points. Minor variations are far from being in agreement, however.

Fig. 15 shows the continuance of the observations during the first 9 or 10 hours of the next day, June 28. Light rains continued at intervals, with westerly wind from midnight to 4:15 a. m.; cloudy, with northerly winds, after that hour. The prevailing tendency at the Monument was toward lower potential, and the diagram shows a strong movement to the negative side between 8 a. m. and 9 a. m.

At the Signal Office, however, the general tendency is toward higher potential, with an apparent participation in a limited degree, in the disturbances between 8 a. m. and 9 a. m.

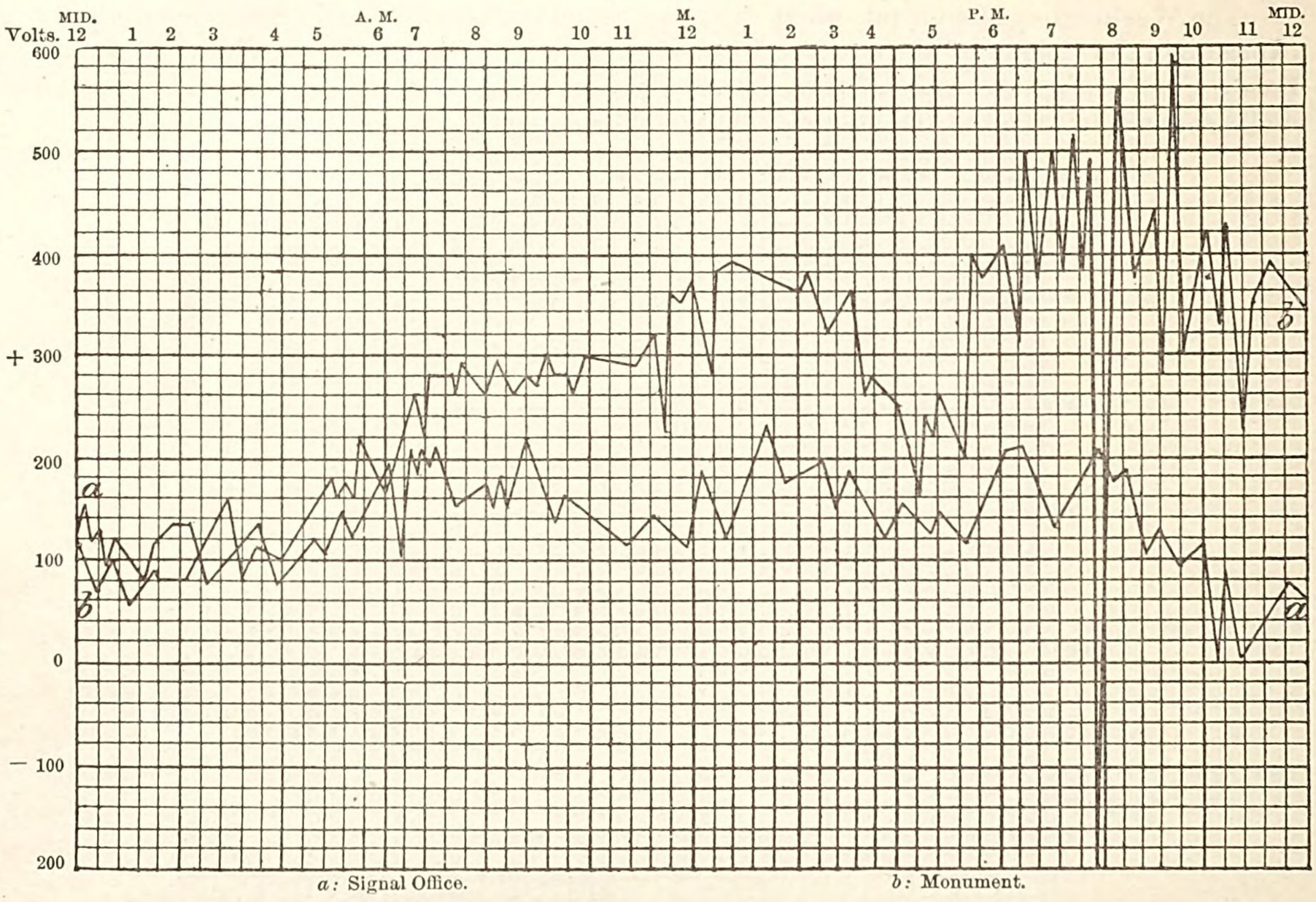


FIG. 14.—Curves showing variations of potential during a series of simultaneous observations taken on top of Washington Monument and at the Signal Office, Washington, D. C., June 27. 1886.

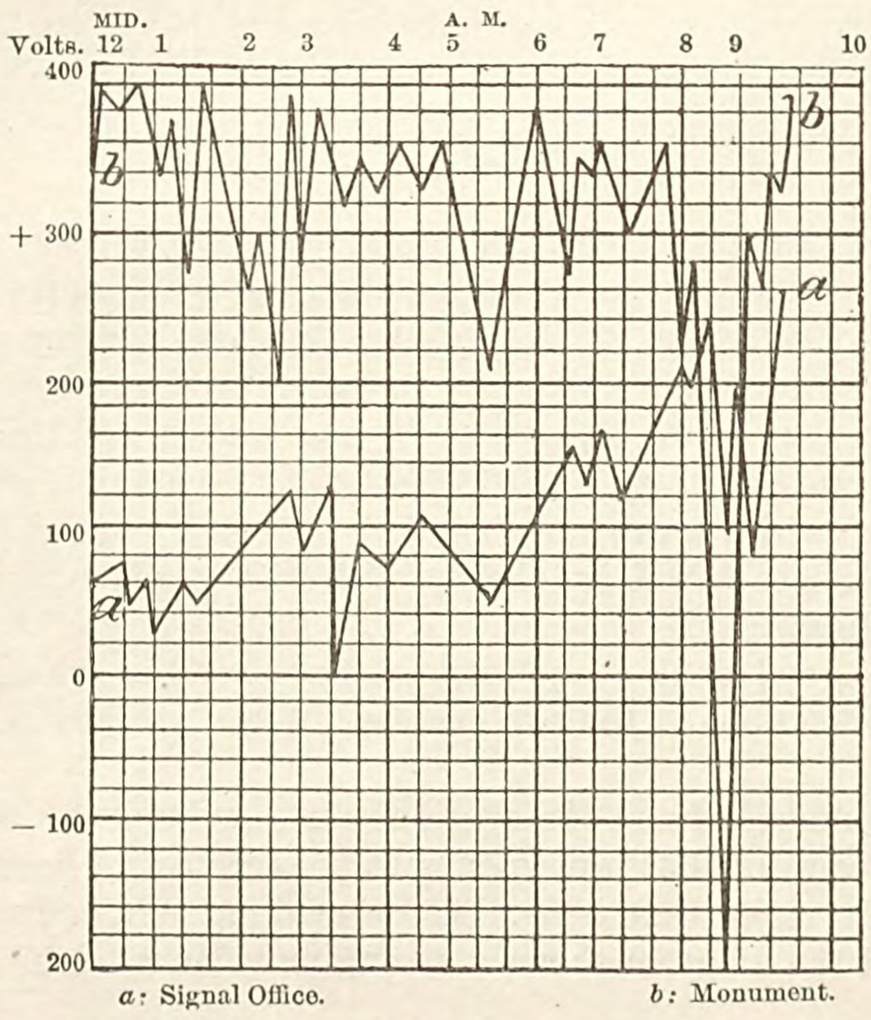


FIG. 15.—Curves showing variations of potential during a series of simultaneous observations taken on top of Washington Monument and at the Signal Office, Washton, D. C., June 28, 1886.

The results of observations made during a part of July 17, 1886, are exhibited in Fig. 16 and show unusual disturbances at the summit of the Monument, which were hardly perceptible at the Signal Office. On that day the sky was cloudless, the atmosphere hazy, the wind from the southwest and light; no indications of rain. During the forenoon the needle at the Monument oscillated almost continually, indicating variable, high, positive potentials, often exceeding the range of the instrument, which was about 3,000 volts.

During the afternoon the movements were less violent, although apparently the meteorological conditions remained sensibly the same. The Signal Office curve shows relatively low potential and little variation.

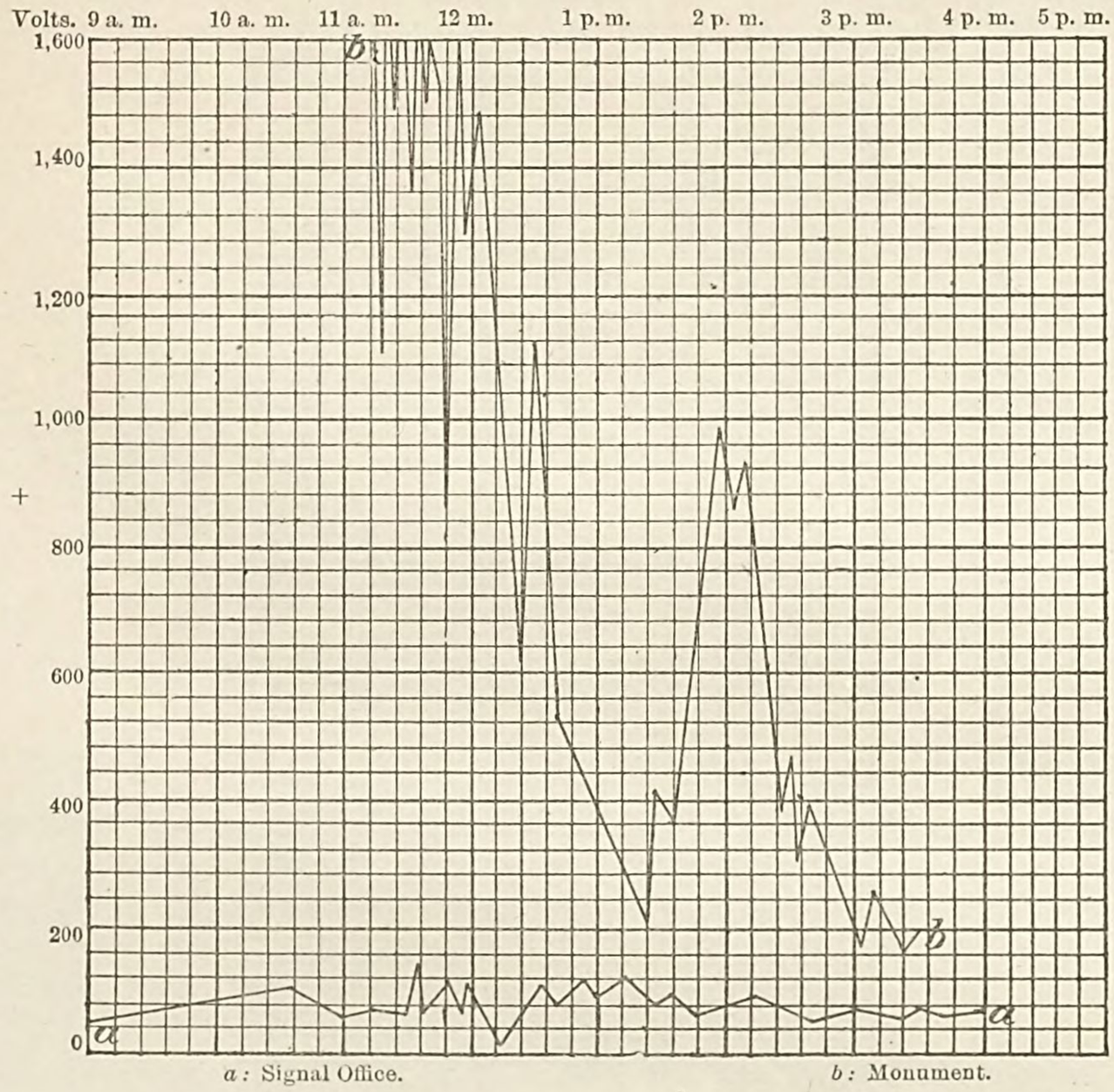


FIG. 16.—Curves showing variations of potential during a series of simultaneous observations taken on top of Washington Monument and at the Signal Office, Washington, D. C., July 17, 1886.

On July 14, 1886, during the progress of a series of simultaneous observations at the Monument and the Signal Office, a thunder squall came up suddenly during the passage of which the observer at the Monument made the following observations: At 2:45 p. m. the sky was covered with a pallium of stratus clouds, and distant thundering was audible; darker cumulus clouds came rapidly from the west, and by 3:15 p. m. the storm was overhead; two very vivid lightning flashes, with sharp and loud thunder, occurred about this time; at 3:40 the storm had passed. The collector was exposed from the window on the south side, the height above the ground being about 508 feet. When connected with the collector the needle was greatly excited, moving from one side to the other rapidly.

The greatest deflection noticed showed a negative potential equivalent to about 3,000 volts. Sparks, however, were constantly passing between the wire-suspending fiber and the neck of the brass top-plate of the electrometer. In addition to the rapid oscillatory movements of the needle there was an up-and-down jumping disturbance. As it was impossible to do anything with the electrometer as then arranged, the wire connecting it with the collector was removed and a wire connected with the ground, held about 3 millimeters away from the side of the collector. Sparks passed continuously at a rate of about 10 to 15 per second.

By measurement the length of the spark was 4 millimetres. There were two intense lightning flashes about 3:10 p. m., seemingly in close proximity to the Monument. Simultaneously with the lightning the following phenomena were noticed:

(1) An alteration in the character of the stream of water issuing from the nozzle of the collector.

Previous to the flash, and apparently depending upon the degree of electrification, the stream would be twisted and split into many fine threads and sprays; but instantly, with the occurrence of the flash, the stream resumed its normal character, maintaining it for a few seconds and then gradually becoming more and more distorted until the occurrence of another flash, when the same state of things was repeated.

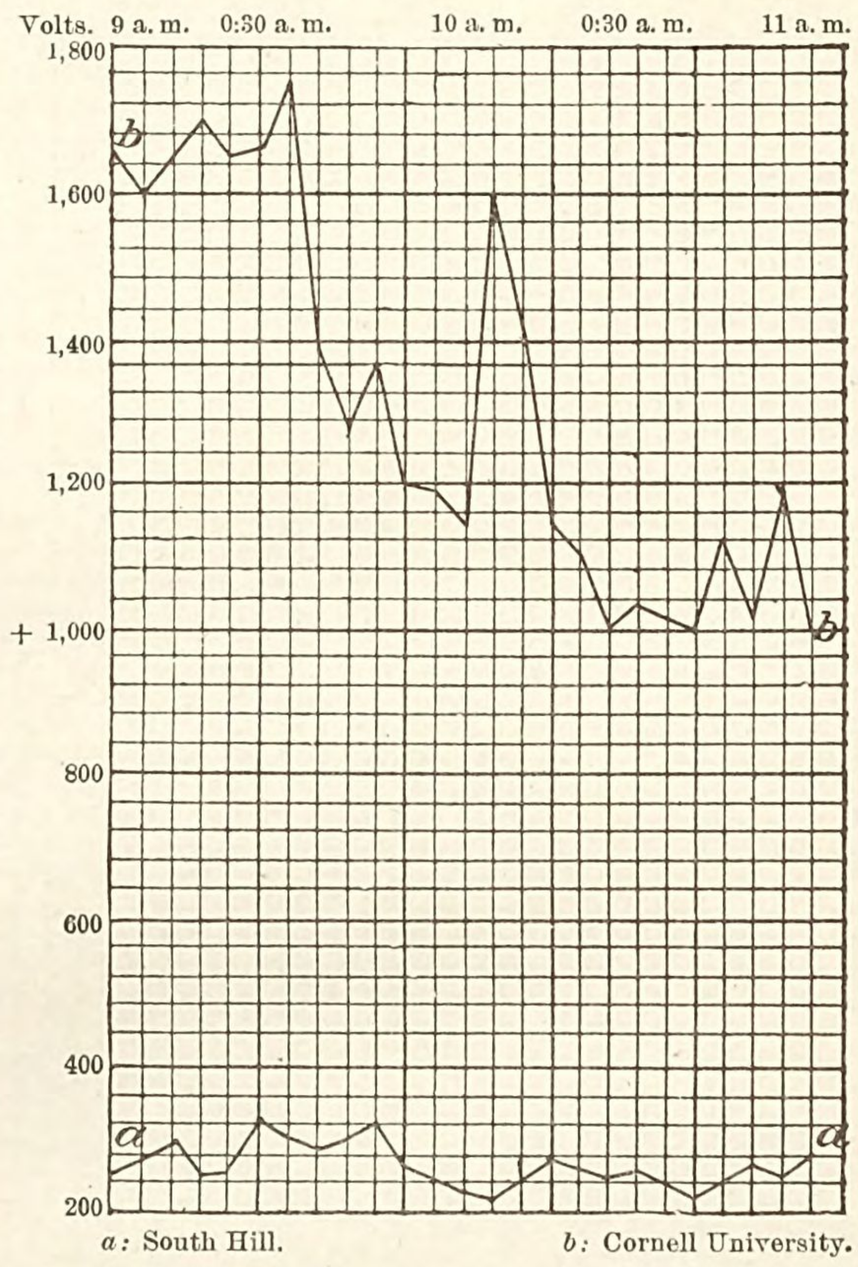


FIG. 17.—Curves showing the variations in potential during a series of observations taken at intervals of five minutes, at South Hill, Ithaca, N. Y., and at Cornell University, Ithaca, N. Y., March 10, 1888.

(2) There was noticed a cessation of the sparking between the collector and the ground wire simultaneously with the flash.

Then, long before thunder was heard (in one case 8 seconds), the sparking would again begin and increase rapidly. At 3:40 p. m. the storm appeared to be over, and at this time the electrometer indications were positive and much more constant. Phenomena similar to the above were observed, during the progress of the work, at nearly all of the stations.

Results very similar to those obtained in Washington on July 17 are shown in Fig. 17, which represents a series of 5 minute observations at Ithaca, N. Y. The regular station of that point was at Cornell University, which is situated on a hill about 400 feet higher than the level of Cayuga lake and the valley surrounding it.

The elevated position of this station was doubtless one of the principal causes of the extreme ranges and rapid variation of potential so often observed there.

By the coöperation of Mr. E. T. Turner a station was established temporarily at South Hill, not far from the University but about 105 metres lower.

The observations shown in Fig. 17 were made on the morning of March 10, 1888. The sky was about seven-tenths cloudy, and a fresh south wind was blowing.

There is a general movement towards lower potential shown in both curves, but otherwise there is little resemblance between the two. Essentially the same thing is shown in Fig. 18 when further simultaneous observations made at the same stations are exhibited. On May 9, 1888, the weather was damp and sultry; about seven-tenths of the sky was hidden by clouds, and a fresh southeast wind was blowing. On May 21 the weather was clear with a light northerly wind.

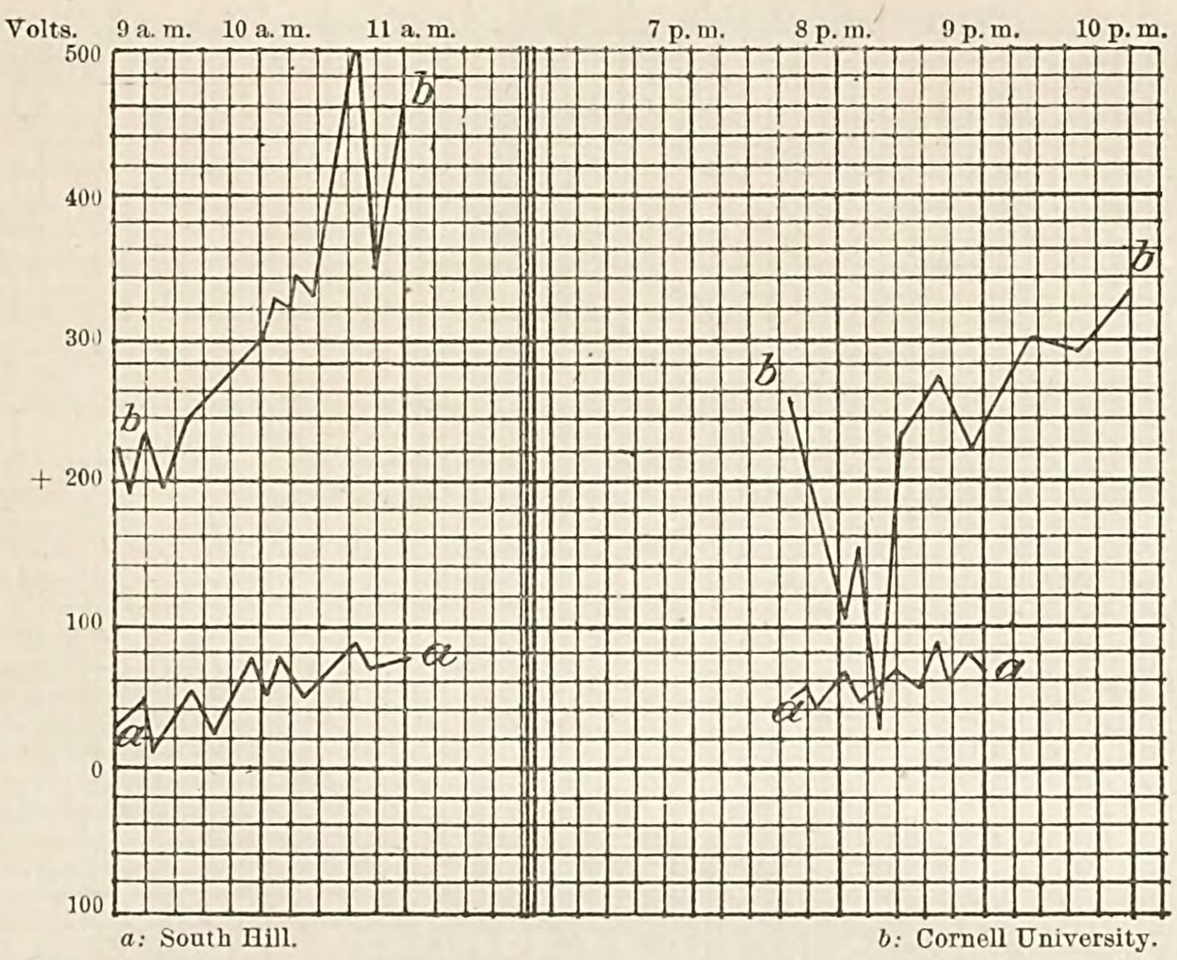


FIG. 18.—Curves showing the variations in potential during the time simultaneous observations were taken at South Hill and Cornell University, Ithaca, N. Y., May 9 and 21, 1888.

SIMULTANEOUS OBSERVATIONS AT STATIONS WIDELY SEPARATED.

As soon as several of the regular stations were equipped, a series of simultaneous observations at short intervals was undertaken, for the purpose of determining whether any special electrical conditions were likely to prevail over a large district, and particularly whether variations going on at one place were preceded, accompanied, or followed by similar variations at other places. Arrangements were made for a series of 5-minute observations, extending through 72 hours at Ithaca, N. Y., Columbus, Ohio, Washington, D. C., and Baltimore, Md.

The readings began at noon on April 7, 1886, and continued until noon of the 10th. The results are shown in Figs. 19, 20, and 21, each chart showing 24 hours.

On the second day the photographic register at Baltimore failed to do its work properly, and as no arrangements for eye observations had been made, the record for the second day of that station was lost. A brief synopsis of the weather at the various stations during these observations is as follows:

FIRST TWENTY-FOUR HOURS.

Ithaca, N. Y.—Light snow from 12 m. on the 7th to 3:40 p. m.; cloudy from 3:40 to 5:40 p. m.; light snow 5:40 p. m. to 3 a. m. on the 8th; cloudy from 3 a. m. to 12 m.; temperature stationary, about zero; brisk northwesterly wind.

Columbus, Ohio.—Cloudy from 12 m. to 8 p. m.; clear 8 p. m. to 12 m. on the 8th; falling temperature; high northwesterly wind 12 m. to 5 p. m.; light northwesterly 5 p. m. to 9 p. m.; gentle northerly wind 9 p. m. to 4 a. m. on the 8th; gentle southwesterly wind from 4 a. m. to 12 m.

Washington, D. C.—Cloudy with light showers of rain from 12 m. to 5:30 p. m.; cloudy from 5:30 p. m. to 12 m. on the 8th; falling temperature; light westerly wind 12 m. to 5 p. m.; brisk northwesterly wind 5 p. m. to 12 m. on the 8th.

Baltimore, Md.—Cloudy with light rain 12:35 to 12:45 p. m. and from 4:45 to 7 p.m., followed by clear weather; falling temperature; brisk northwesterly wind.

SECOND TWENTY-FOUR HOURS.

Ithaca, N. Y.—Fair from 12 m. to 4 p. m.; clear from 4 p. m. to 12 m. on the 9th; rising temperature; fresh northwesterly wind 12 m. to 6 p. m.; gentle northwesterly wind from 6 p. m. to 6 a. m. on the 9th; gentle southeasterly wind from 6 a. m. to 12 m.

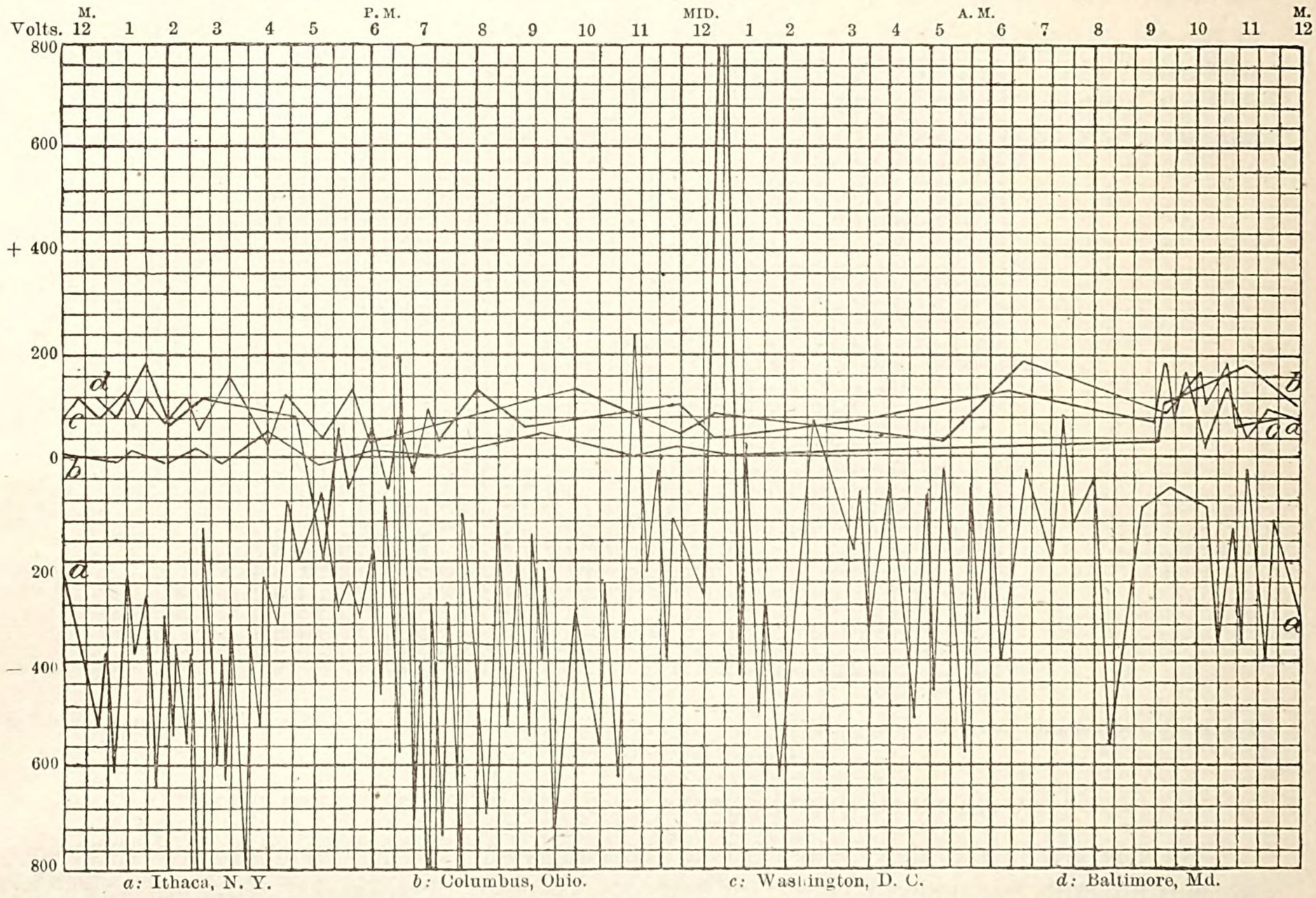


FIG. 19.—Curves showing the variations in potential during a series of simultaneous observations taken at intervals of five minutes from 12 m. April 7 to 12 m. April 8, 1886.

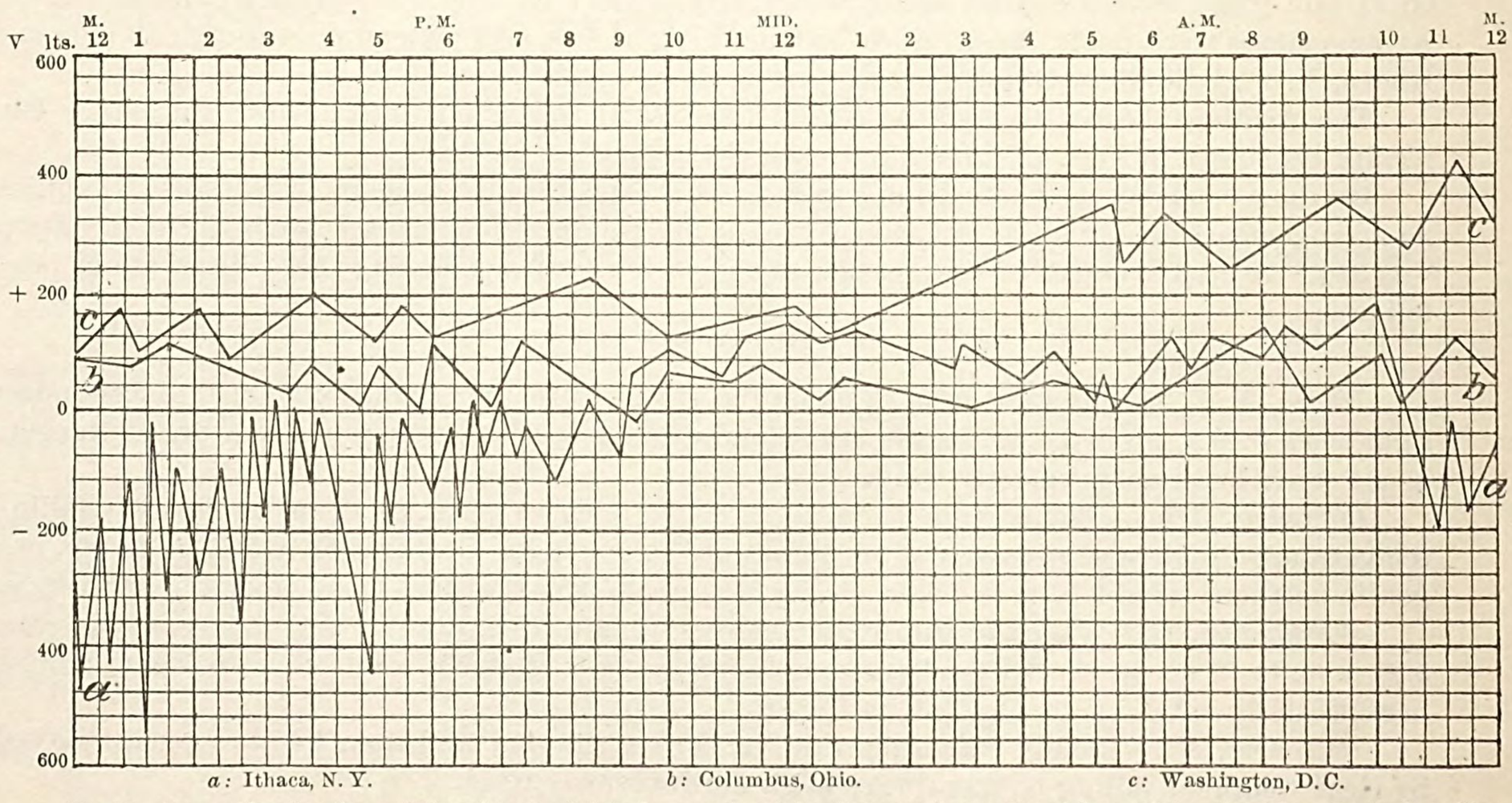


FIG. 20.—Curves showing the variations in potential during a series of simultaneous observations taken at intervals of five minutes from 12 m. April 8 to 12 m. April 9, 1886.

Columbus, Ohio.—Cloudless sky, slowly rising temperature, light southerly winds.

Washington, D. C.—Cloudy from 12 m. to 3 p. m.; fair 3 to 4 p m.; clear 4 p. m. to 12 m. on the 9th; rising temperature; light northwesterly winds.

THIRD TWENTY FOUR HOURS.

Ithaca, N. Y.—Fair weather, about five-tenths cirro-stratus clouds during the time, stationary temperature, gentle variable winds.

Columbus, Ohio.—Cloudy from 12 m. to 10 p. m.; clear from 10 p. m. to 5 a. m. on the 10th; cloudy 5 a. m to 12 m.; rising temperature; fresh southerly winds.

Washington, D. C.—Clear weather, stationary temperature, light southerly winds.

Baltimore, Md.—Clear weather, rising temperature, light southerly winds.

It should be noted that the scale on which the diagrams are made does not permit of the representation of minor variations in potential which were constantly occurring. The principal changes and general movements, however, are well shown. Throughout the last two days the conditions as to weather were essentially the same at all of the stations. In some instances the diagrams show changes of considerable similarity; in others, so unlike that the coincidence of movement can hardly be regarded as other than accidental.

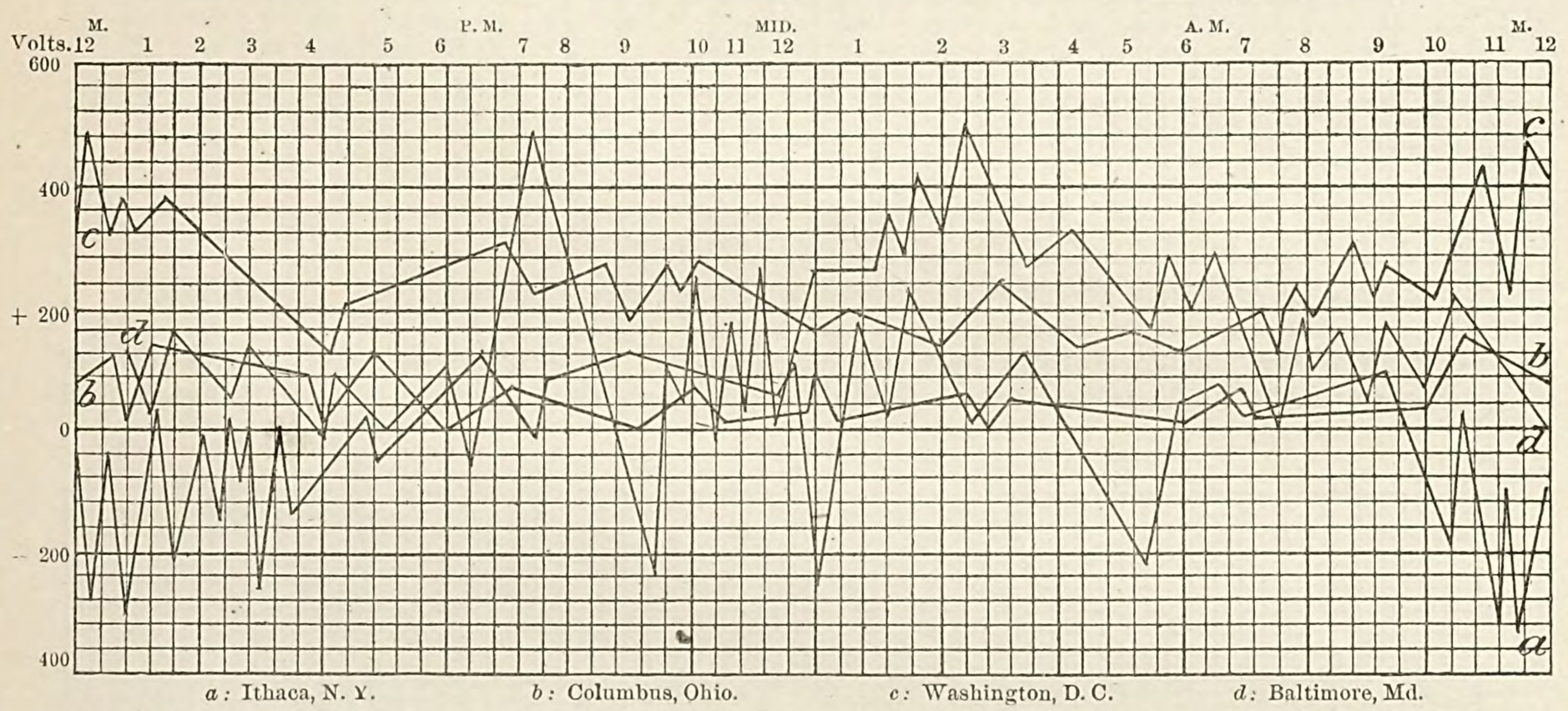


FIG. 21.—Curves showing the variations in potential during a series of simultaneous observations taken at intervals of five minutes from 12 m. April 9 to 12 m. April 10, 1886.

In February, 1888, another series of simultaneous observations, extending through 24 hours, was undertaken at Boston, Washington, Ithaca, and Terre Haute, beginning at 12 m. on the 17th and ending at 12 m. on the 18th. During this time the three northern stations were under the influence of two slight barometric depressions. One of these centers was over Nova Scotia and influenced the weather conditions at Boston from 12 m. on the 17th until 12 midnight.

The other was over the lake regions, influencing the conditions at Terre Haute during the whole 24 hours, and at Ithaca from 7 p. m. on the 17th, to 4 a. m. on the 18th. The pressure at Washington was nearly stationary during the 24 hours. It was sensibly stationary at all of the stations from 6 a. m. until 12 m. on the 18th. During the night of the 17th and early morning of the 18th there was a light fall of snow at the lower lake stations, throughout New York and the New England States, and at Philadelphia, Pa. At Washington the clouds on the night of the 17th were so thin that stars were visible through them; and the same thing was true where the precipitation at no time exceeded a "snow mist."

To avoid confusion, the potential diagrams are shown separately for each station in Figs. 22, 23, 24, and 25, and notes as to weather conditions for each hour are added.

An examination of these diagrams reveals some points of resemblance between the movements

at Boston and Washington, and also between those at Ithaca and Terre Haute. An unusual disturbance seems to have occurred between 8 p. m. and 10 p. m. at both Boston and Washington; a decided rise and fall in potential occurs at Washington at about 7 a. m., which appears to be imitated in some degree at Boston about 8:30 a. m.

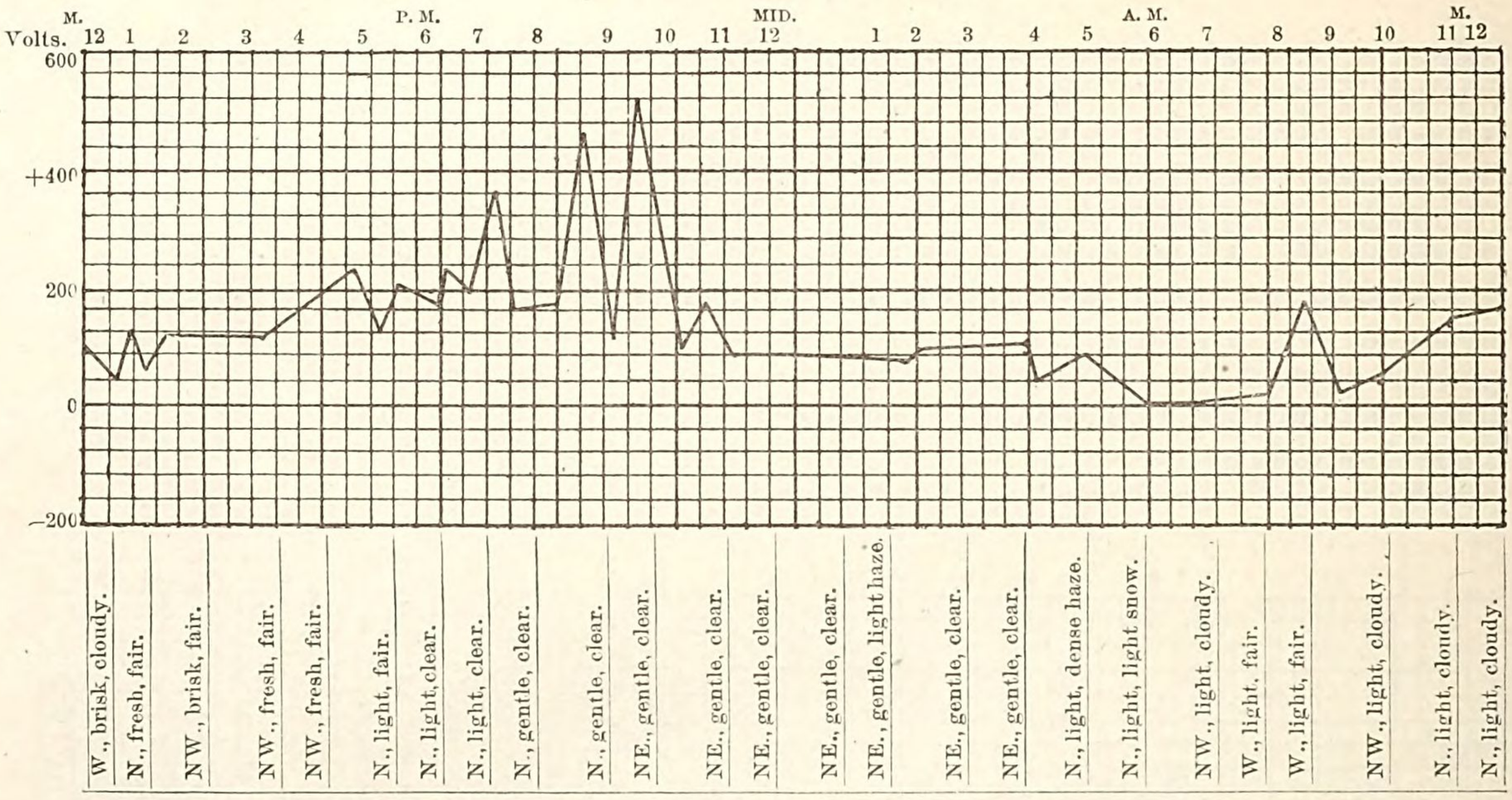


FIG. 22.—Curve showing five minute observations of potential at Boston, Mass., from 12 m. February 17 to 12 m. February 18, 1888.

The general movements, however, are not very similar. At both Ithaca and Terre Haute the range of variation is much greater from midnight until noon than during the first 12 hours, and

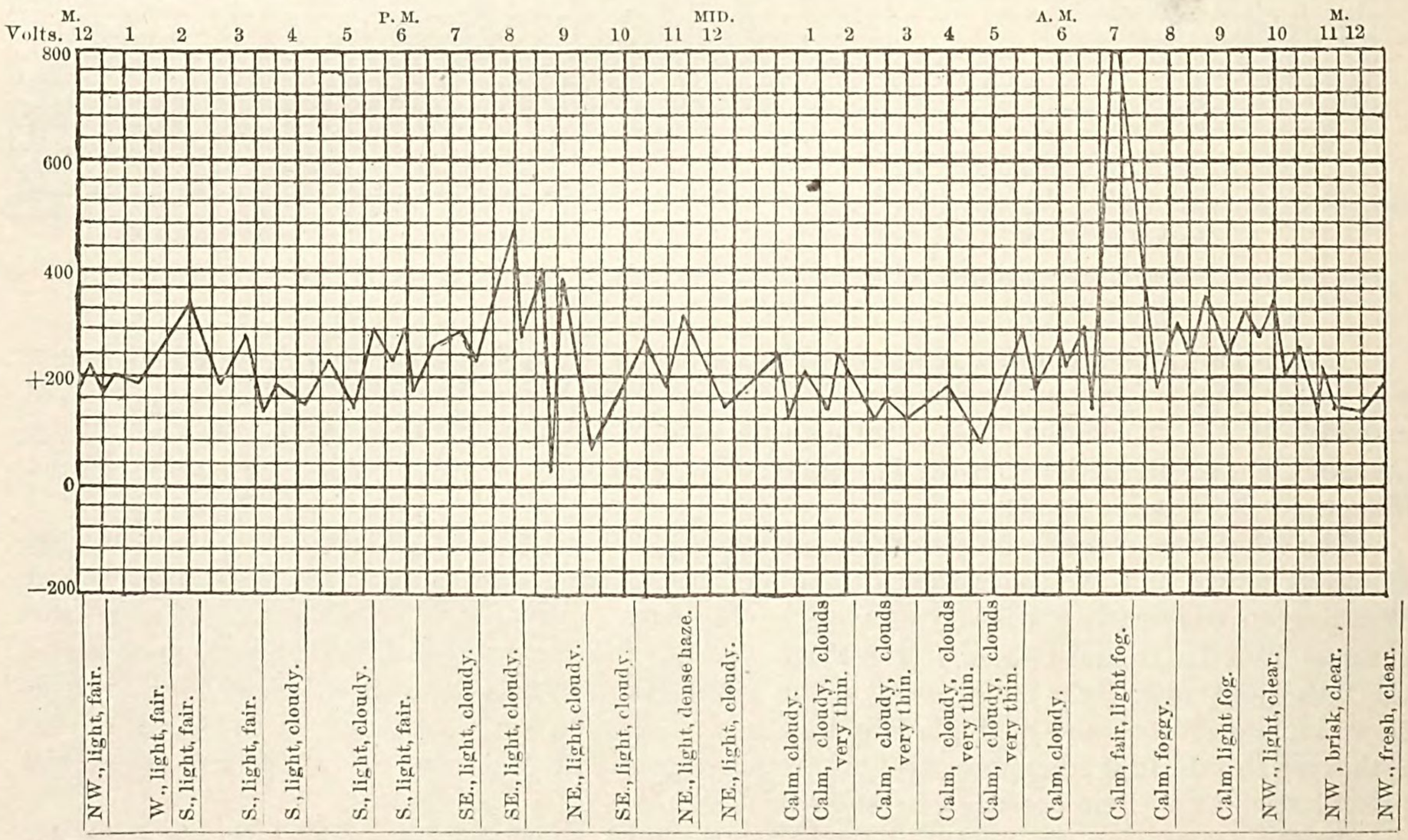


FIG. 23.—Curve showing five-minute observations of potential at Washington, D. C., from 12 m. February 17 to 12 m. February 18, 1888.

both diagrams show a sudden but short drop to negative potential between half past seven and eight in the morning.

It seems difficult to believe that these similarities of movement have no special significance, but it will be observed that there are many simultaneous movements in opposite directions, some of which are little less marked than those referred to.

Occasionally instances occur in which the potential changes at two stations widely separated resemble each other so much that it seems almost certain that for some hours both stations have been subject to the same general electrical influences. Illustrations of this are shown in Figs. 26 and 27, where observations at Washington and Ithaca, taken at the regular hours of observation, on February 10 and 11, 1888, are plotted side by side. At Washington, on the 10th, there was light snow from 9 a. m. to 4 p. m.; light sleet, 4 to 7 p. m.; temperature stationary, at about 19°; light northerly wind.

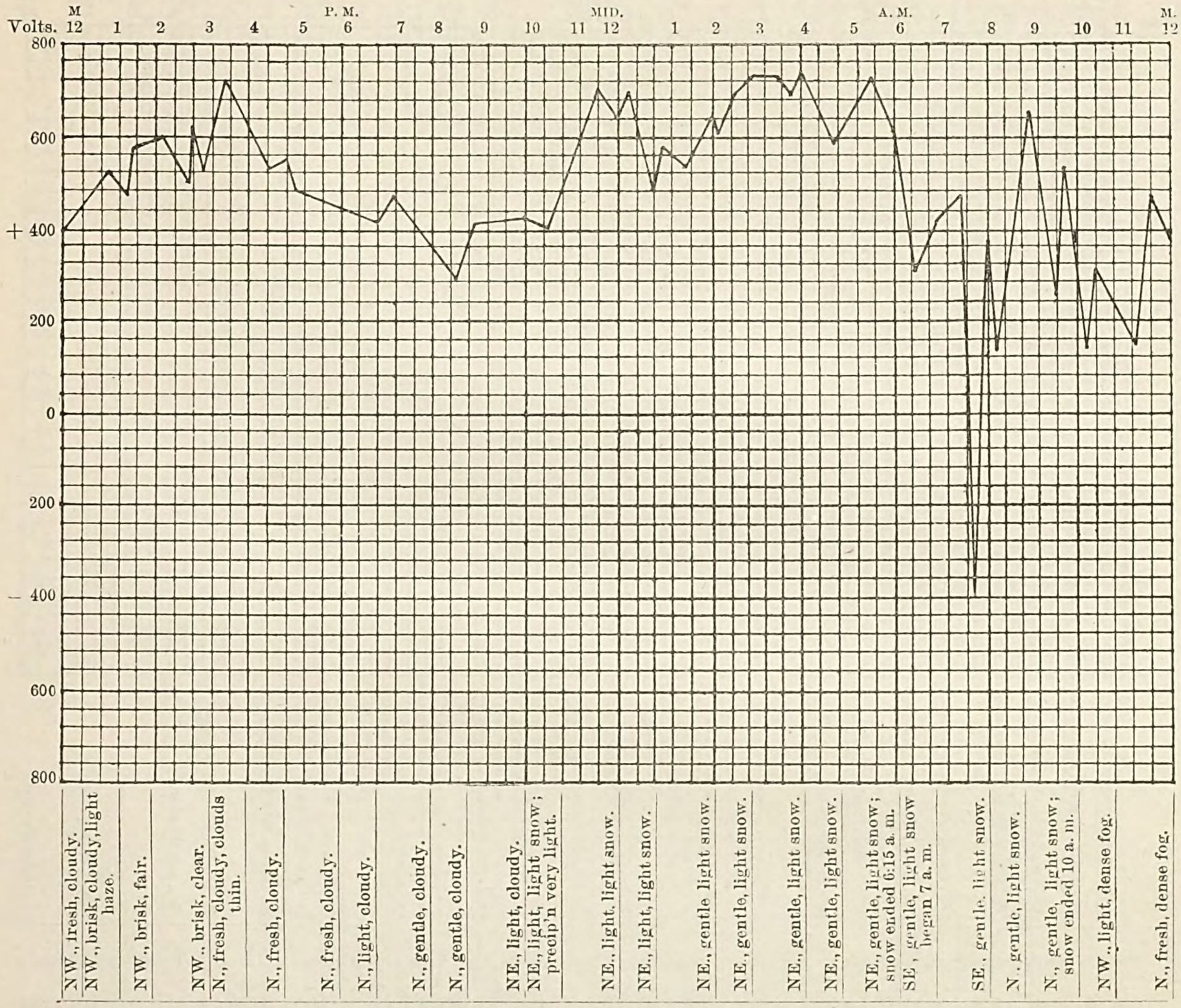


FIG. 24.—Curve showing five-minute observations of potential at Ithaca, N. Y., from 12 m. February 17, to 12 m. February 18, 1888.

At Ithaca, cloudy from 9 a. m. to 3:30 p. m.; very light snow from 3:30 to 6 p. m.; temperature rose from — 9° at 9 a. m. to 12° at 6 p. m.; brisk southeasterly wind all day.

On the 11th, at Washington, sleet fell from 9 to 10 a. m.; light rain from 10 a. m. to 5 p. m.; temperature stationary, at about 31°; light northerly wind.

At Ithaca, cloudy weather, with very light snow, 9:20 to 10:20 a. m.; temperature stationary, at about 22°; gentle southwesterly wind from 10:30 a. m. to 5 p. m.

On February 10 the diagram shows a fall to negative potential at both stations, remaining negative at Washington during the remainder of the observations, while at Ithaca a change to high positive occurs at about 4 p. m.

On the 11th the movements resemble each other very much, although the potential is constantly negative until nearly 1 p. m. at Washington, while it is high positive at Ithaca throughout the day.

SPECIAL OBSERVATIONS.

Several of the regular observers were requested to make special observations, at shorter intervals than usually allowed, on days and occasions when unusual or abnormal electric conditions seemed to prevail. They were directed to record the effect, if any, of local causes, such as dust clouds, haze, mist, etc., and to especially observe the appearance of negative electricity on clear days.

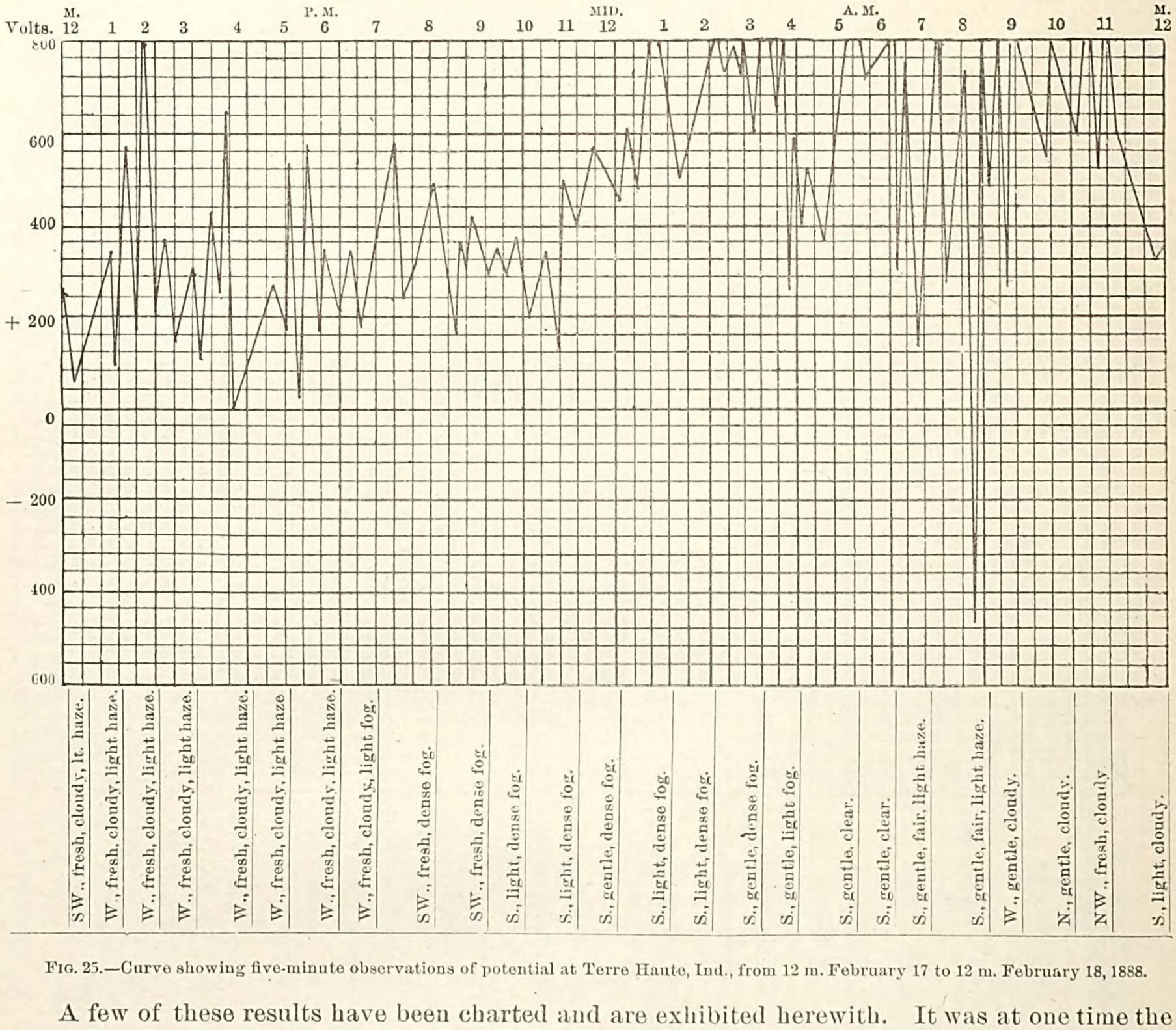


FIG. 25.—Curve showing five-minute observations of potential at Terre Haute, Ind., from 12 m. February 17 to 12 m. February 18, 1888.

A few of these results have been charted and are exhibited herewith. It was at one time the general belief that negative electricity would not be indicated during clear weather, and that it would only be found as an accompaniment of precipitation, if not at the place of observation, in the immediate neighborhood.

Sir William Thomson in his article on atmospheric electricity in Nichol's Cyclopædia, speaks of an observation by Piazzi Smyth, on the summit of the Peak of Teneriffe as "one remarkable exception," and suggests that in this case the test as to equality might have been deceptive. Negative electricity in clear weather was observed, however, at most if not all of the Signal Service stations on numerous occasions during the progress of the work. In many cases precipitation occurred at points from 10 to 100 miles distant, but in others clear weather prevailed over almost the entire country. A number of instances of negative potential during clear weather occurred at Ithaca, where careful attention was given to the matter of special observation by Mr.

Schultz, the observer in charge during 1887 and 1888. Figs. 28, 29, and 30 exhibit some of these observations.

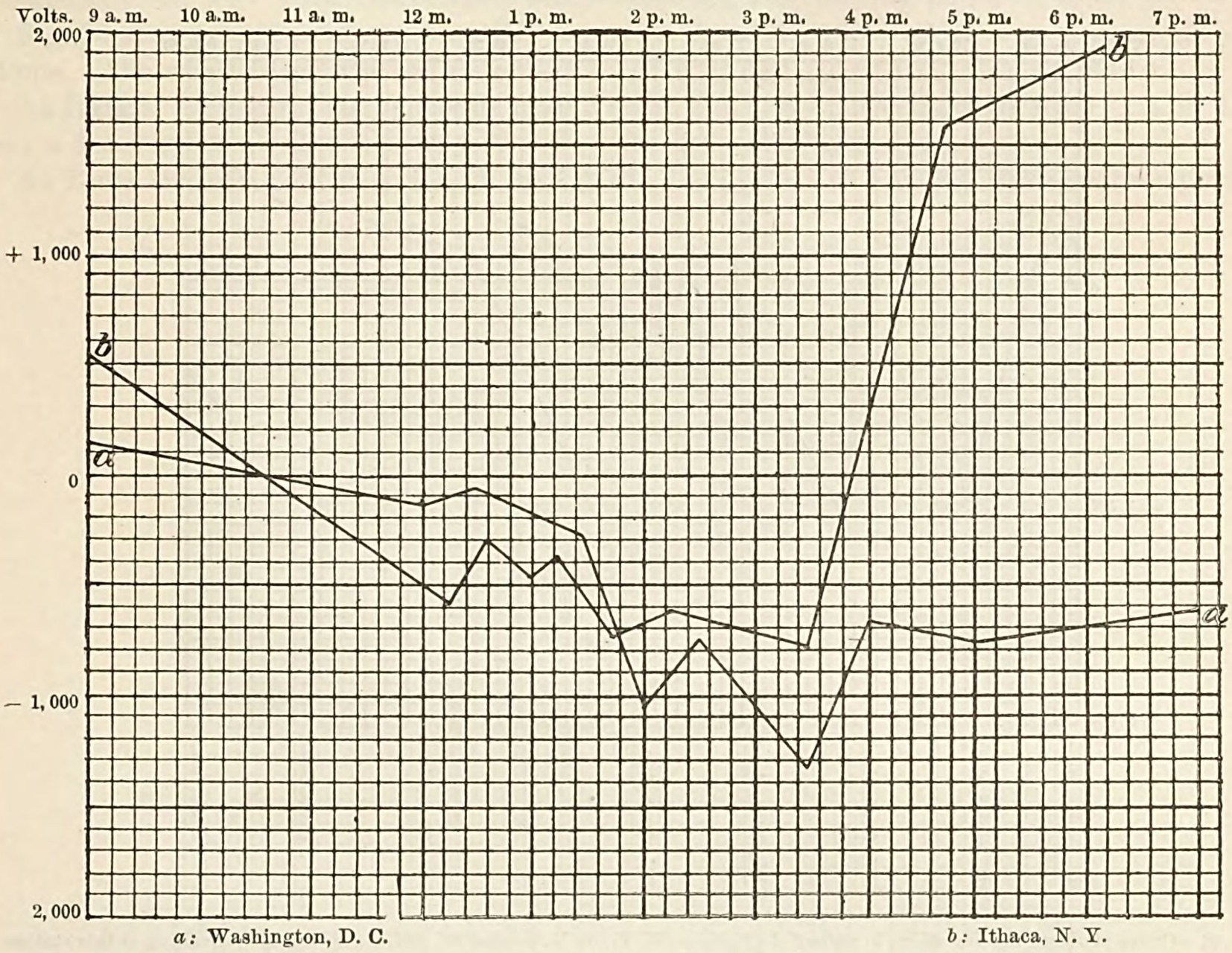


FIG. 26.—Curves showing the variations of potential at Washington, D. C., and Ithaca, N. Y., on February 10, 1888.

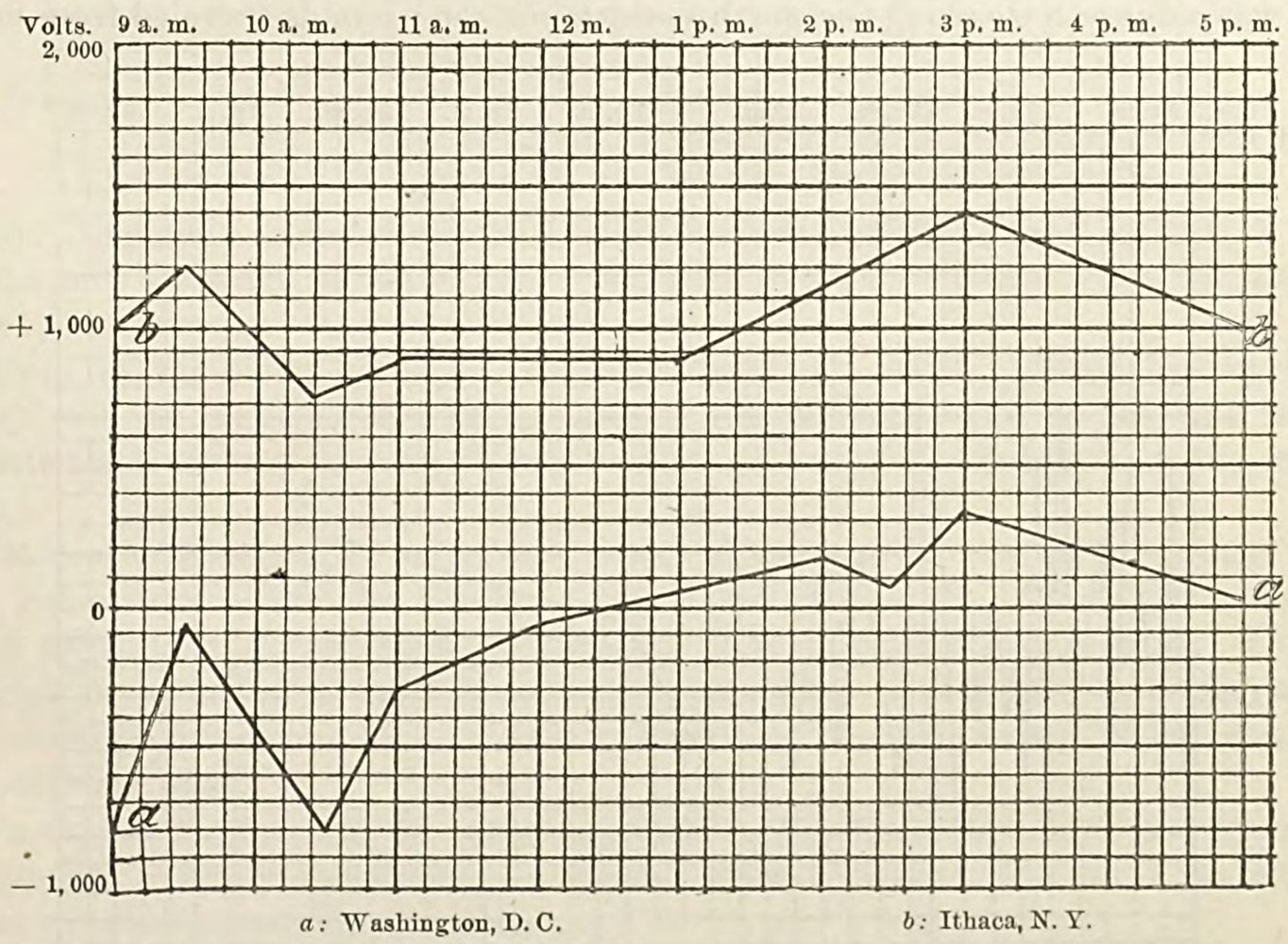


FIG. 27.—Curves showing the variations of potential at Washington, D. C., and Ithaca, N. Y., on February 11, 1888.

Fig. 28 shows observations on November 29, 1887. The weather was clear throughout the day at Ithaca, but snow fell all day at Rochester and Oswego, N. Y.; at all Lower Lake Signal Service stations and at some points about 20 miles distant from the station.

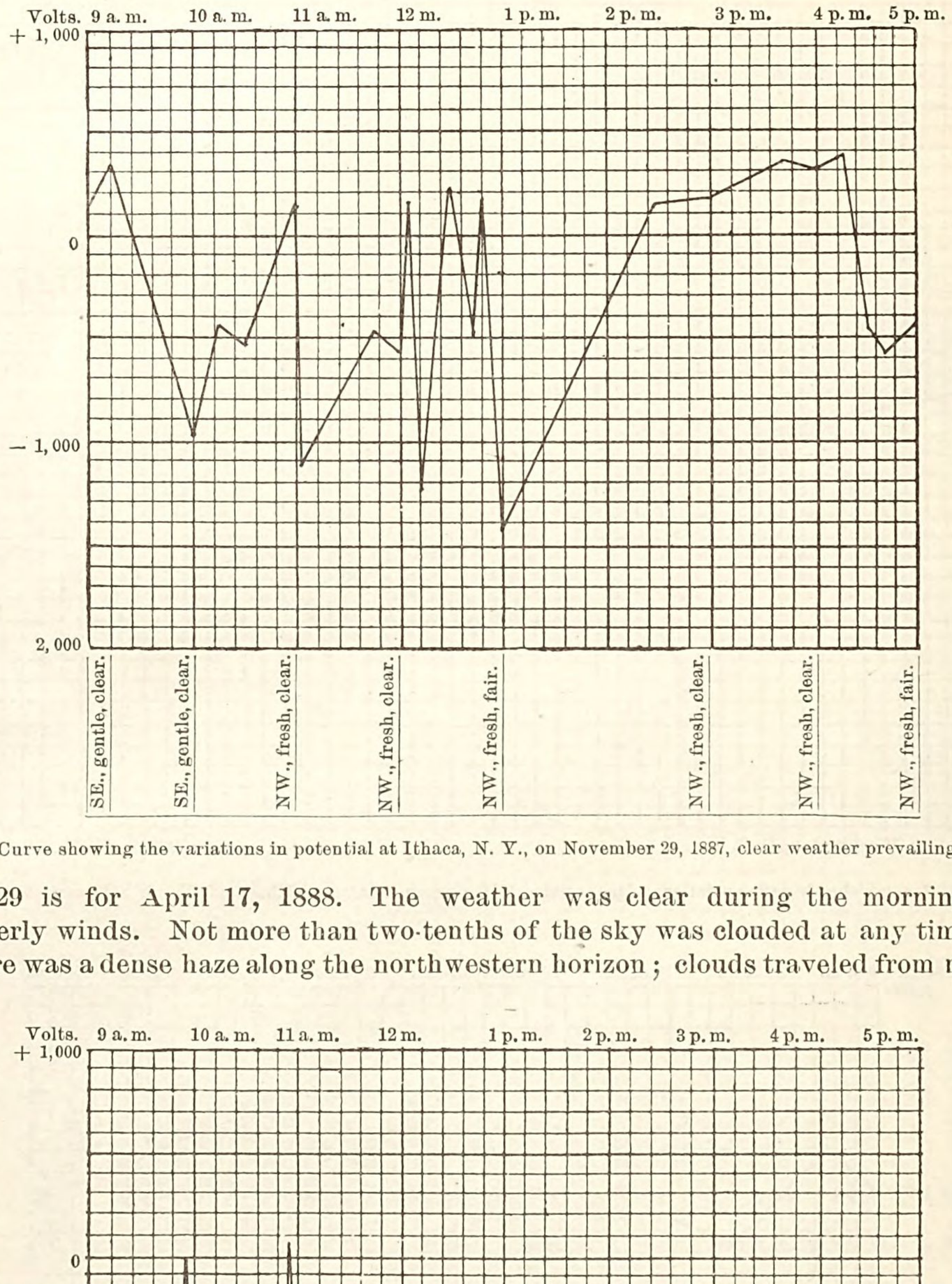


FIG. 28.—Curve showing the variations in potential at Ithaca, N. Y., on November 29, 1887, clear weather prevailing at this station.

Fig. 29 is for April 17, 1888. The weather was clear during the morning with fresh northwesterly winds. Not more than two-tenths of the sky was clouded at any time before 11:30 a. m. There was a dense haze along the northwestern horizon; clouds traveled from north to south.

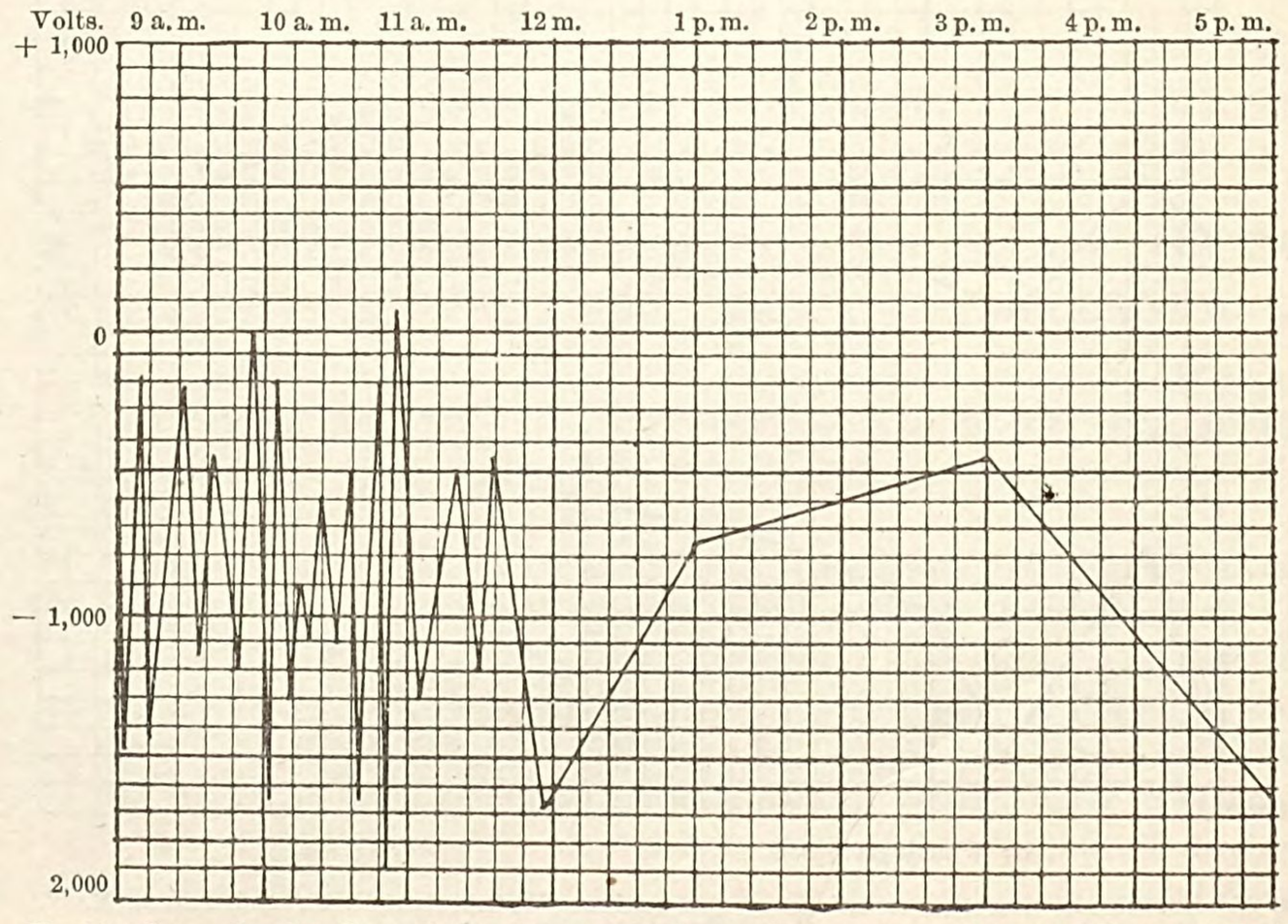


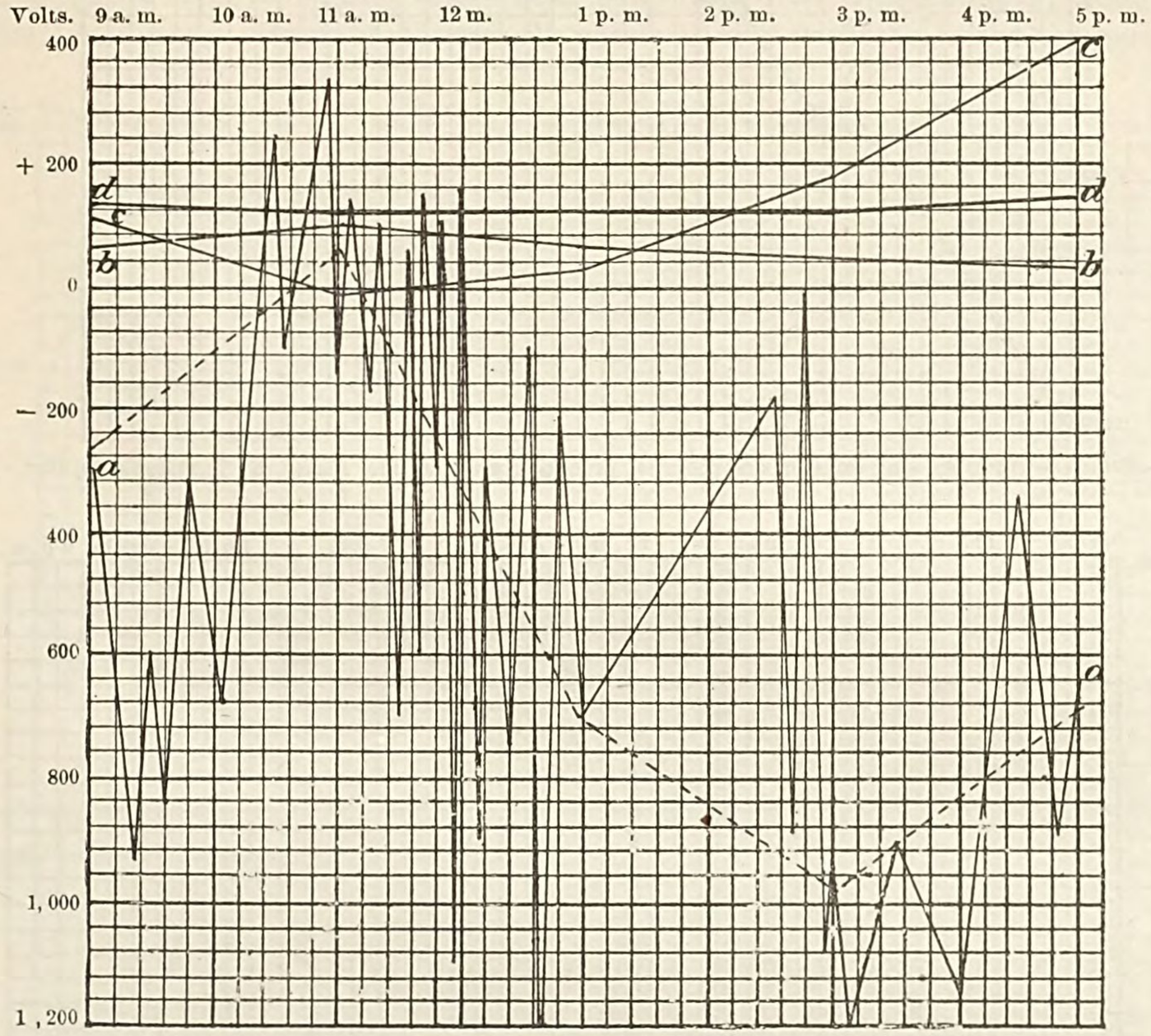
FIG. 29.—Curve showing the variations in potential during clear weather at Ithaca, N. Y., April 17, 1888.

As the cloudiness increased the indications became more steady. During the afternoon the sky was completely clouded and no rapid variations were observed. Light rain and snow fell at all Canadian and New York Lower Lake stations during the morning and afternoon.

Fig. 30 shows variations of potential on a day, April 25, 1888, which was clear at all of the stations. The weather synopsis is as follows:

At Ithaca: One-tenth cirrus clouds from 9 to 11 a m.; sky perfectly clear from 11 a. m. to 4:30 p. m.; a few very small clouds from 4:30 to 5 p. m.; light northerly wind.

At Terre Haute: clear from 9 a. m. to 1 p. m.; fair from 1 to 5 p. m.; fresh southerly wind.



a: Ithaca, N. Y. *b:* Terre Haute, Ind. *c:* Boston, Mass. *d:* Washington, D. C.
FIG. 30.—Curves showing the variations in potential on a cloudless day, April 25, 1888.

At Boston: No clouds except occasional small patches; negative reading at 11 a. m., without a visible cloud, and no wind to raise dust. No other negative value observed during the day. Light haze in the afternoon; fresh easterly wind.

Washington, D. C.: clear all day; light northeasterly wind. Rapid fluctuations during the entire day will be noticed as having occurred at Ithaca. The dotted line is drawn for comparison with the lines representing the other stations and shows potential at the regular hours of observation.

A few illustrations may also be given of the electrometer records preceding and during precipitation, not including thunder storms. Fig. 31 for October 20, 1887, shows a steady change from a strong negative at the 9 o'clock observation to a steady but low positive. There were no rapid variations in potential at any time during the day. Until 10:30 a. m. the weather was unusually pleasant at Ithaca and at surrounding stations. The sky was perfectly clear and there was a light southerly wind.

At 10:30 a. m. the wind suddenly increased in force, cloudiness increased rapidly, and by 11:30 a. m. the station was within a well-developed storm. Rain began at 7:05 p. m. Rain fell throughout the Lower Lake region during the evening.

Fig. 32 shows variations of potential on a rainy day at the same station, Ithaca, N. Y.

The greatest fluctuations occurred from 12 to 12:30 p. m. There was no precipitation from 12:05 to 12:25 p. m., but during that time the clouds were very low and enveloped the station. The

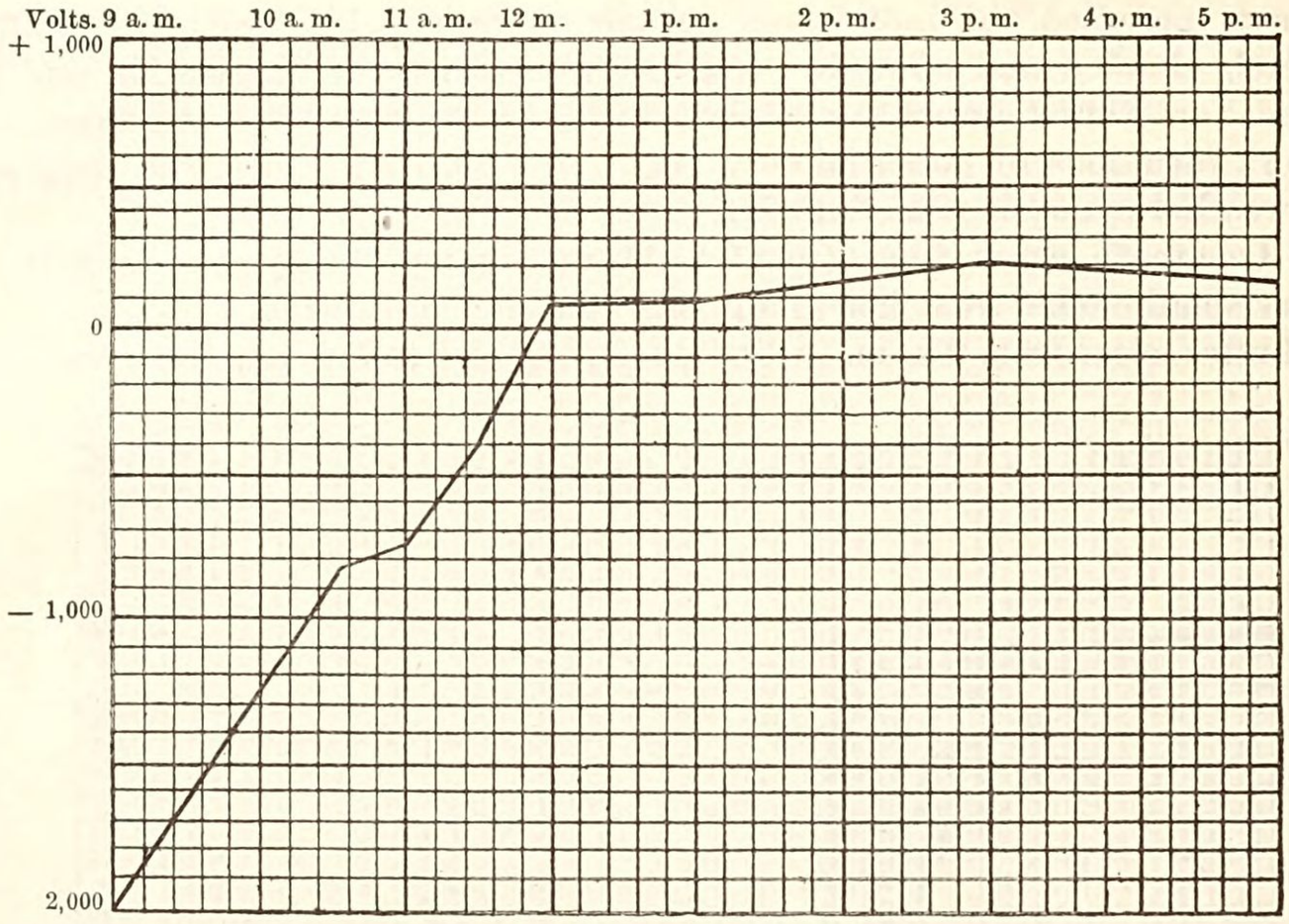


FIG. 31.—Curve showing variations of potential preceding precipitation, Ithaca, N. Y., October 20, 1887.

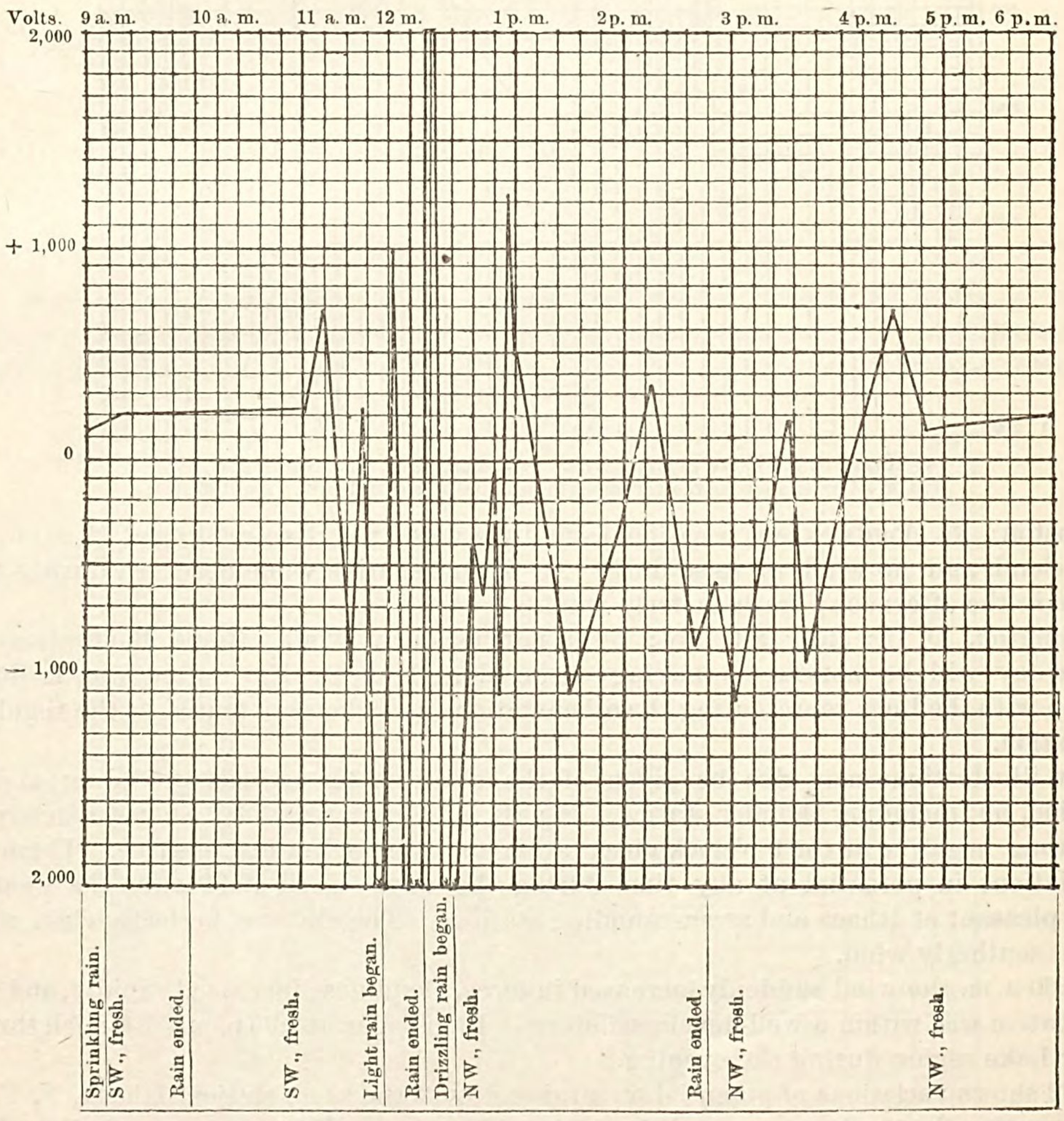


FIG. 32.—Curve showing the variations in potential on a rainy day, May 16, 1888, at Ithaca, N. Y.

small stars at the upper and lower limits of the diagram indicate where sparking occurred between the needle and the quadrants of the electrometer. Fig. 33 also shows potential changes before, during, and after precipitation on what would ordinarily be called a "rainy day." The station was Ithaca and the day May 18, 1888.

Fig. 34 exhibits observations taken at Terre Haute on a cloudy day.

Rain fell at Chicago, nearly 200 miles away, between noon and 3 p. m.

Fig. 35 shows observations at Ithaca while rain was falling at New York City and stations in its vicinity. At Ithaca the sky was clear from 9 to 9:40 a. m. Cloudiness increased from one-tenth at 9:40 to five-tenths at 11 a. m., then decreased. Sky clear from 3 to 3:40 p. m.; about four-tenths clouded from 4 to 6 p. m. Brisk northwesterly winds all day with stationary temperature.

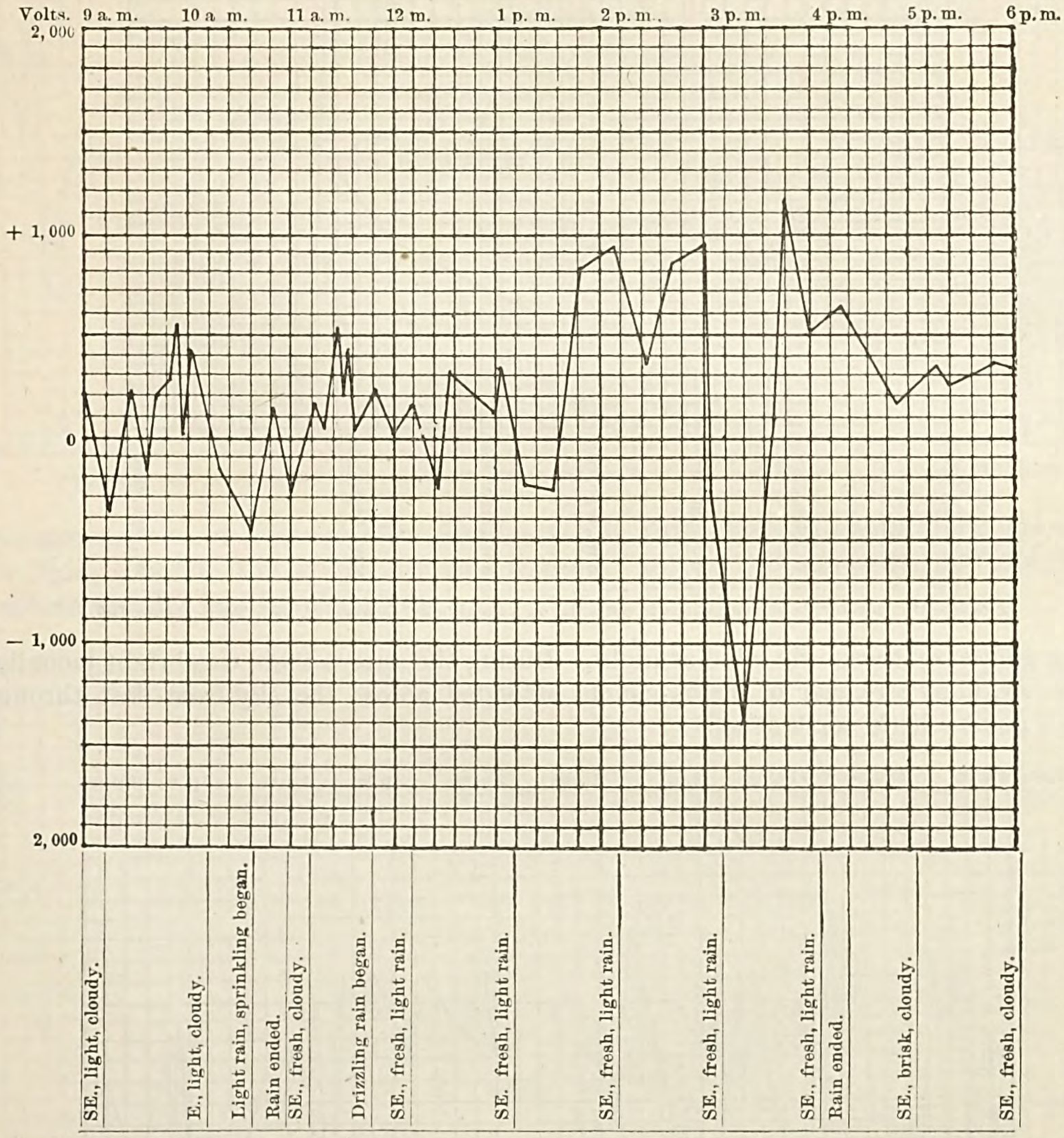


FIG. 33.—Curve showing variations of potential before, during, and after precipitation on a rainy day, May 18, 1888, Ithaca, N. Y.

Fig. 36 shows observations of potential, mostly negative, during April 12, 1888, at Ithaca. From 11 a. m. to 6 p. m. the weather was cloudy; very light snow fell from 2:20 to 3:20 p. m. The sky was perfectly clear after 6 p. m. at Ithaca, and at the 10 p. m. observation clear sky was reported from all stations in the Canadian Lower Lake region, in Ohio, New York (except at Oswego), Pennsylvania, and New England (except at Block Island). Snow fell after midnight at all New-England stations and at Albany, N. Y. No snow at Ithaca; brisk northwesterly wind all day. A faint aurora was observed from 8 to 11 p. m. It is impossible to say whether the tolerably marked fluctuations of the needle during this time are to be in any way attributed to the aurora. A few

weeks later an opportunity occurred for observing the behavior of the electrometer during the occurrence of a brilliant aurora, and the result is shown in Fig. 37.

The weather was cloudy during the morning, fair during the afternoon, and clear at night; the barometer was stationary, the temperature rising; a brisk northwesterly wind blew during the

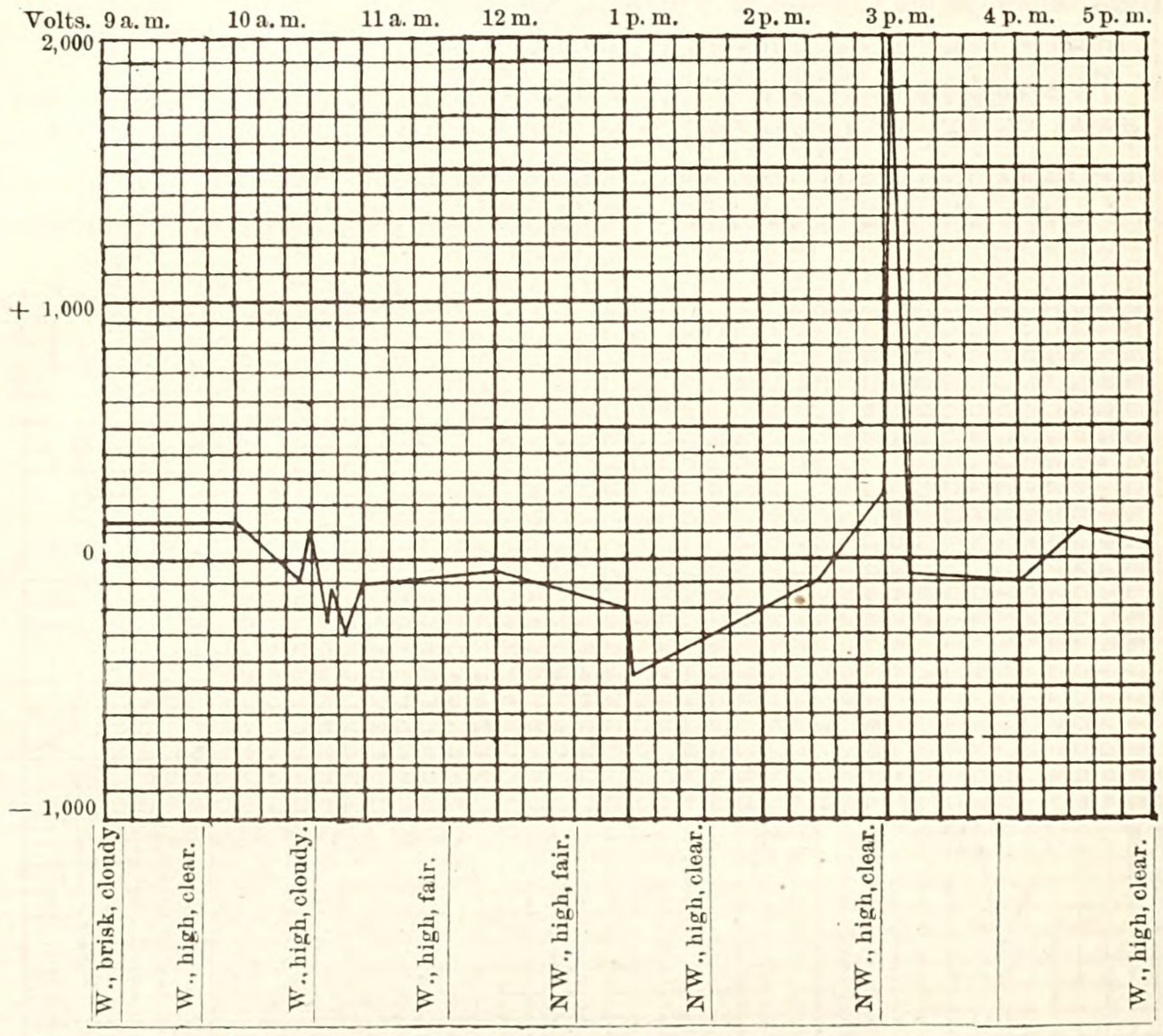


FIG. 34.—Curve showing the variations in potential on a cloudy day, October 21, 1887, Terre Haute, Ind.

day and a gentle southeasterly wind at night. During the aurora there was bright moonlight; a single narrow, filmy streamer of cirrus clouds extended across the sky from east through the zenith to a point a little north of west.

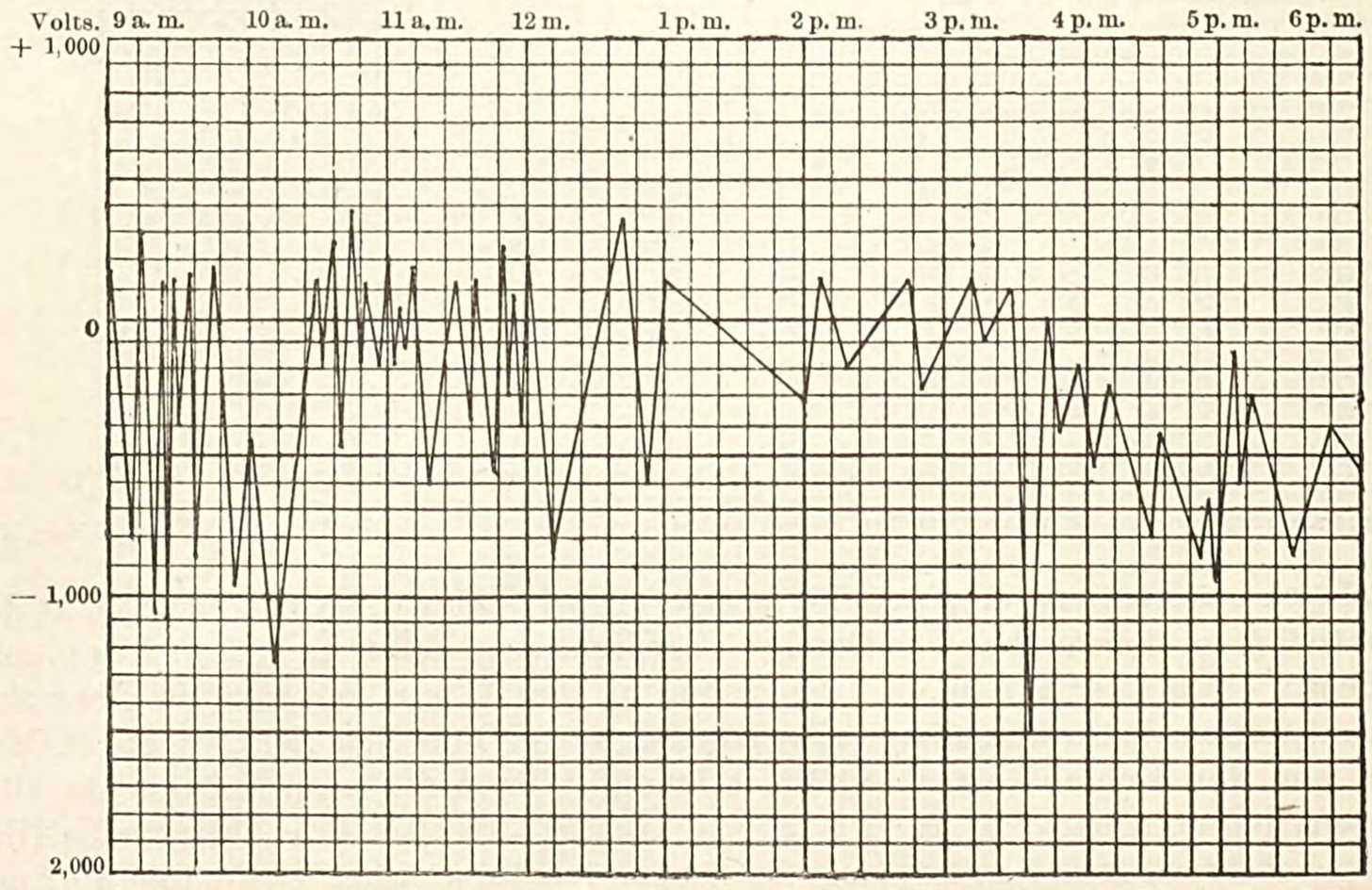


FIG. 35.—Curve showing the variations of potential at Ithaca, N. Y., on April 16, 1888, while rain was falling at New York City and stations in its vicinity.

At 10:30 p. m. it disappeared, except at the zenith, and there it was broken into small cirro-stratus clouds extending southeast to northwest. Notwithstanding the brightness of the moon the aurora was unusually brilliant from 8:30 p. m. until after midnight. Bright, broad, colored streamers were observed at long intervals along the northern horizon. Deflections of the needle did not occur simultaneously with the appearance of streamers.

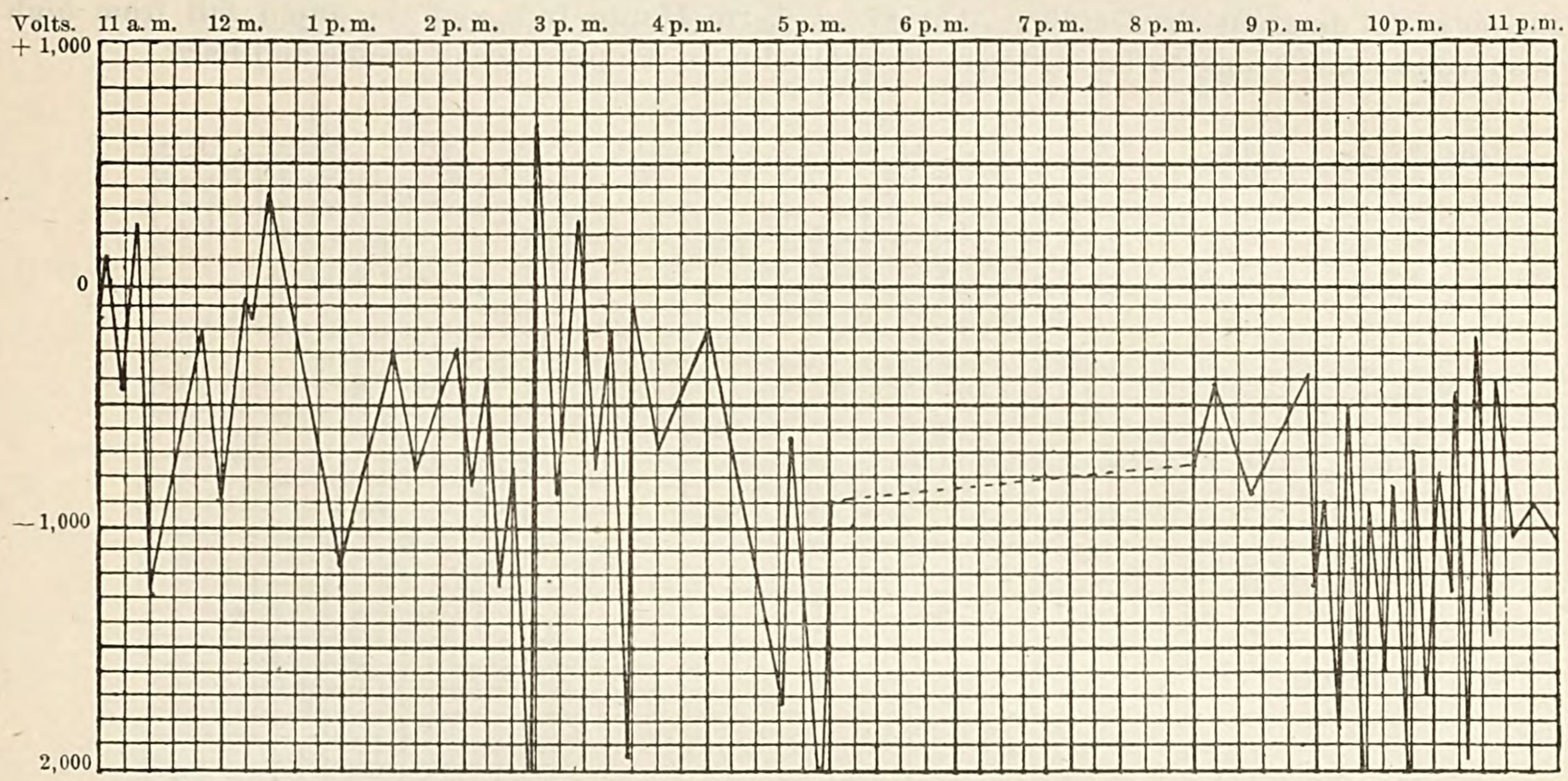


FIG. 36.—Curve showing the variations in potential at Ithaca, N. Y., on April 12, 1888, from 11 a. m. to 11 p. m.

No streamers were observed after 10:30 p. m., at which time the aurora became a diffused yellow light, covering the whole northern horizon. During the appearance of the aurora the atmosphere was unusually transparent.

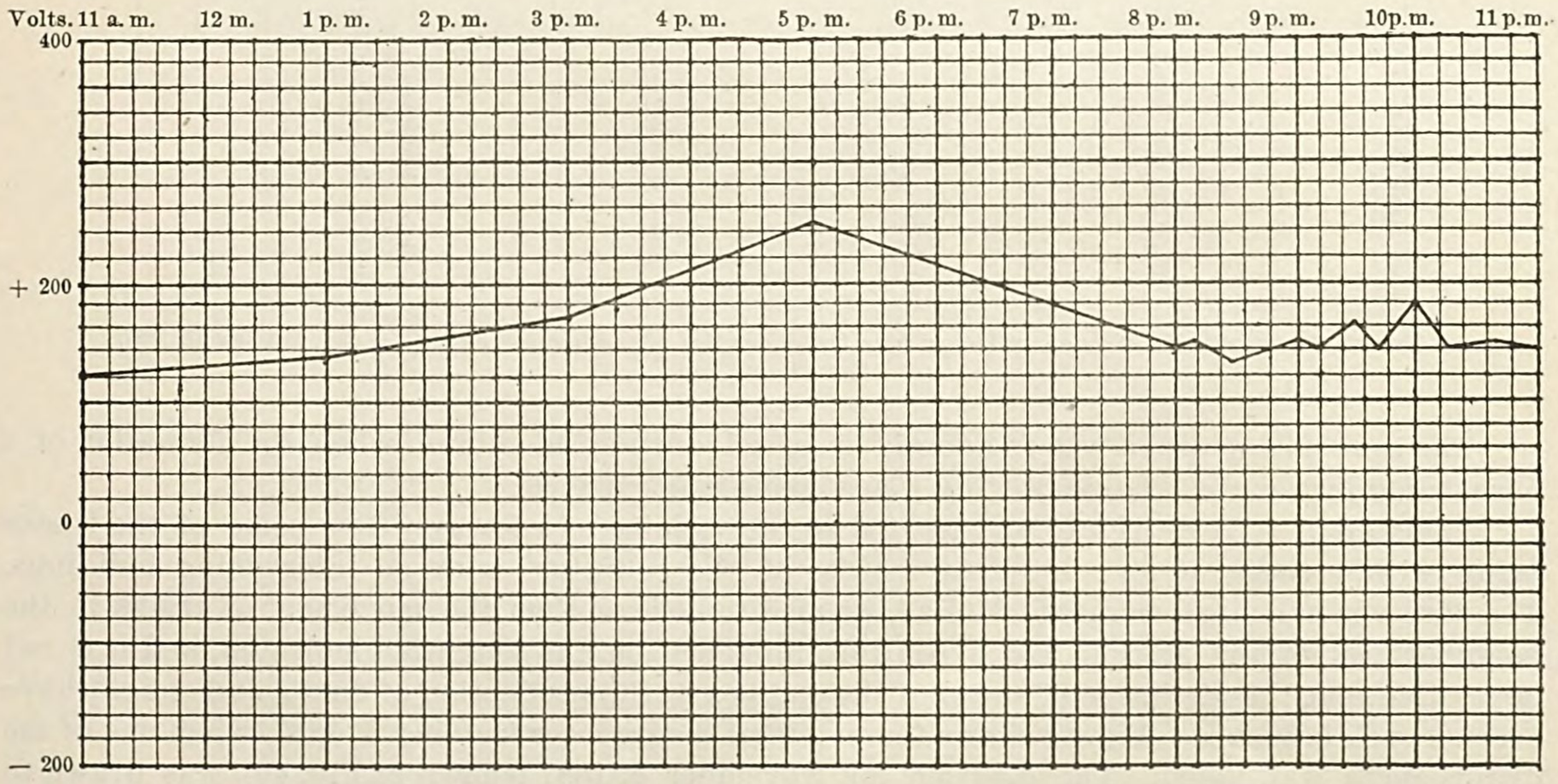


FIG. 37.—Curve showing potentials on a day on which a brilliant aurora was observed, May 20, 1888, Ithaca, N. Y.

It will be observed that the indications of the electrometer were positive throughout the day and night, and that no unusual fluctuations occurred.

The effect of dust, haze, smoke, etc., in producing negative potential has been noticed by more than one observer.

Several instances of the action of clouds of dust were noted by Sergeant Morrill, at Boston. On March 7, 1888, in the afternoon, the potential was observed to fall rapidly from —90 to —270 upon the rising of an especially heavy cloud of dust, and similar phenomena were observed on April 7. On June 27, from 1 to 3 p. m., the potential was very variable and generally negative.

A fall of potential could be certainly predicted when a dust cloud was seen rising. On other days when high winds and dust clouds prevailed negative potential was observed. Fig. 38 shows the potential diagram for October 31, 1887, at Terre Haute, Ind., and the rapid fall from high positive to negative potential is almost certainly due to the presence of smoke and haze.

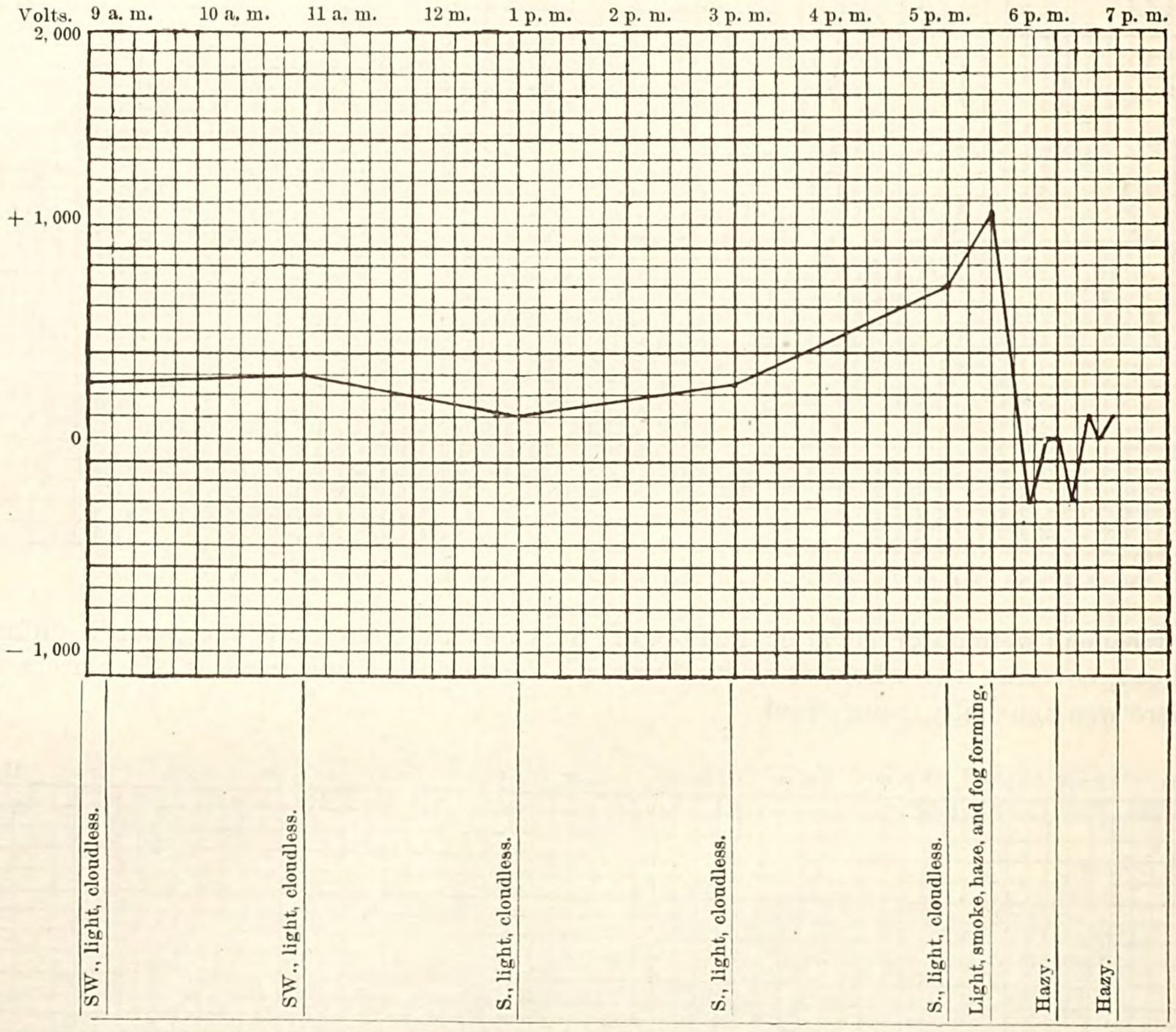


FIG. 38.—Curve showing effect of smoke and haze formations just after sunset on a cloudless day, October 31, 1887, Terre Haute, Ind.

The same phenomenon was frequently observed during the autumn when the formation of a haze or fog just as the sun was setting was a common occurrence.

The station at Terre Haute was located in the vicinity of railway yards, some of the tracks being within three or four hundred metres of the collectors with no intervening buildings. The observer in charge, Sergeant McRae, was led to believe that the movement of trains in the neighborhood of the station had a sensible influence on the potential indicated, and it is not impossible that the discharge of steam of the engines or the production of dust clouds might have exerted such influence. Fig. 39 shows the potential diagram for October 5, 1887, when one of the disturbances was noted. The diagram for November 5, 1887 (shown in Fig. 40), was drawn to show the effect of a morning fog, as well as the supposed effect of a moving train. The passage of a train in the afternoon is noted, under conditions likely to show an influence, but none was detected.

Fig. 41 shows the potential at the same station on October 13, 1887, a cloudless day with clear weather at all surrounding stations and a high wind prevailing. Very high positive

potential was noted previous to the high wind, sparking between needle and quadrants taking place. During the continuance of the high wind, however, the potential was low positive and unusually steady.

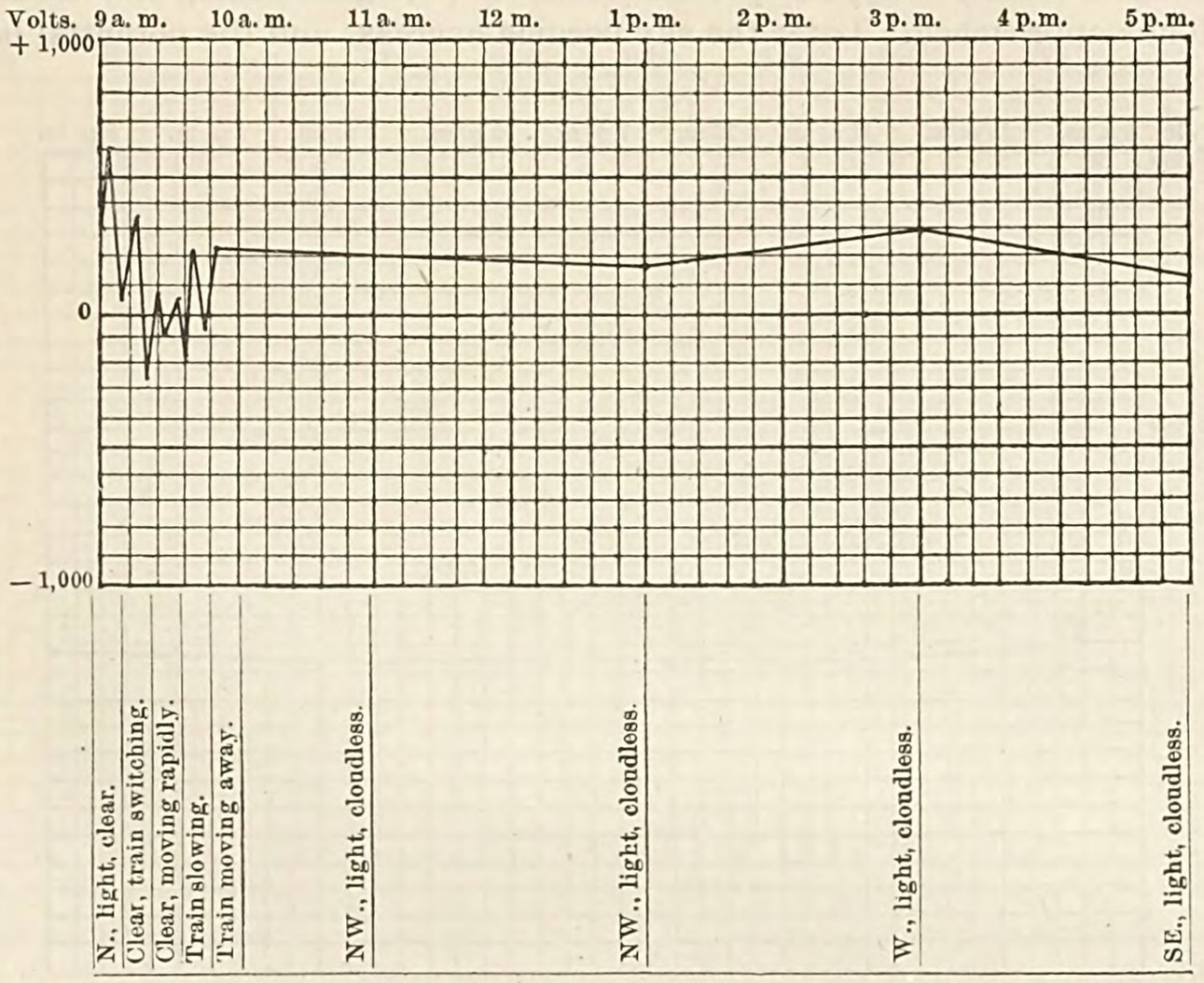


FIG. 39.—Curve showing supposed effect of a passing train upon the potential on a clear day, October 5, 1887, Terre Haute, Ind.

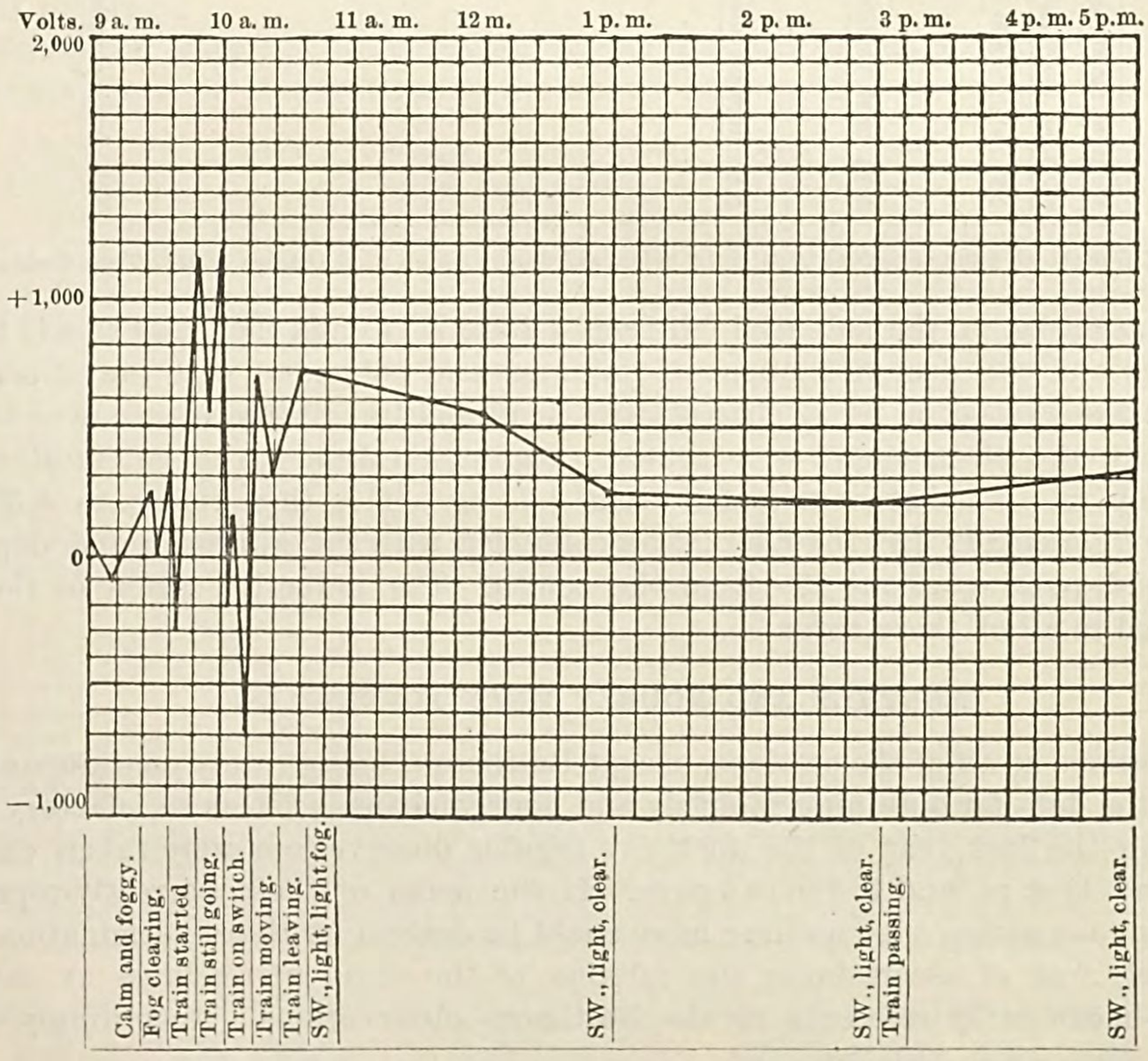


FIG. 40.—Curve showing the variations in potential during a fog in the morning, November 5, 1887, Terre Haute, Ind.

The direct action of a single cloud or group of clouds in producing a fall of potential was often observed. Among other instances Sergeant Morrill at Boston noted the following: In the morning of January 3, 1888, the potential had been steadily positive. At 11:30 a. m. it was +32, from which it fell steadily at the approach toward the zenith of a small cumulus cloud, reaching —21. As this cloud passed away, the potential rose to +6, again falling to —31 as a larger mass of cumulus clouds approached. Later the sky became overcast and the potential became steadily negative.

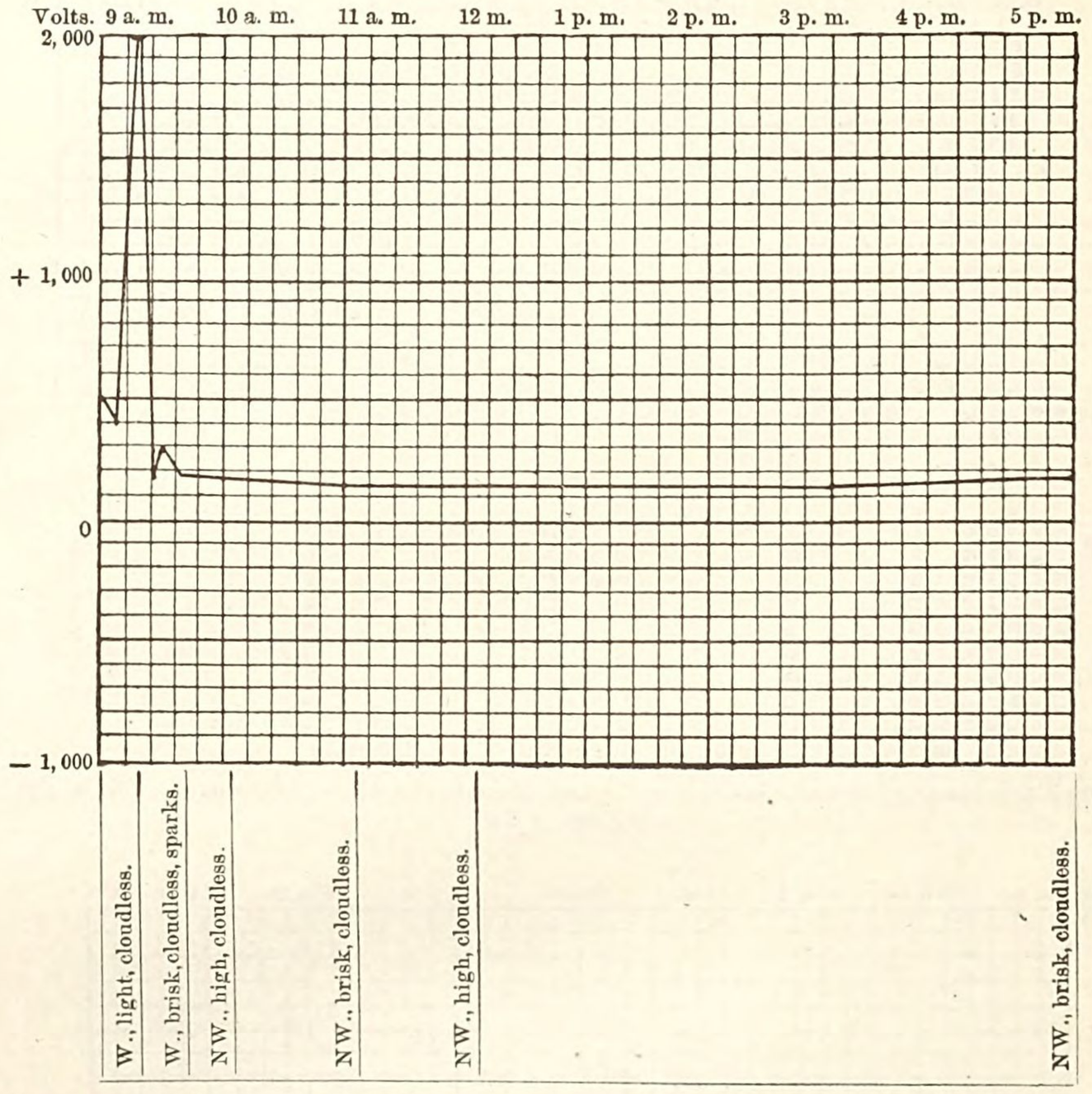


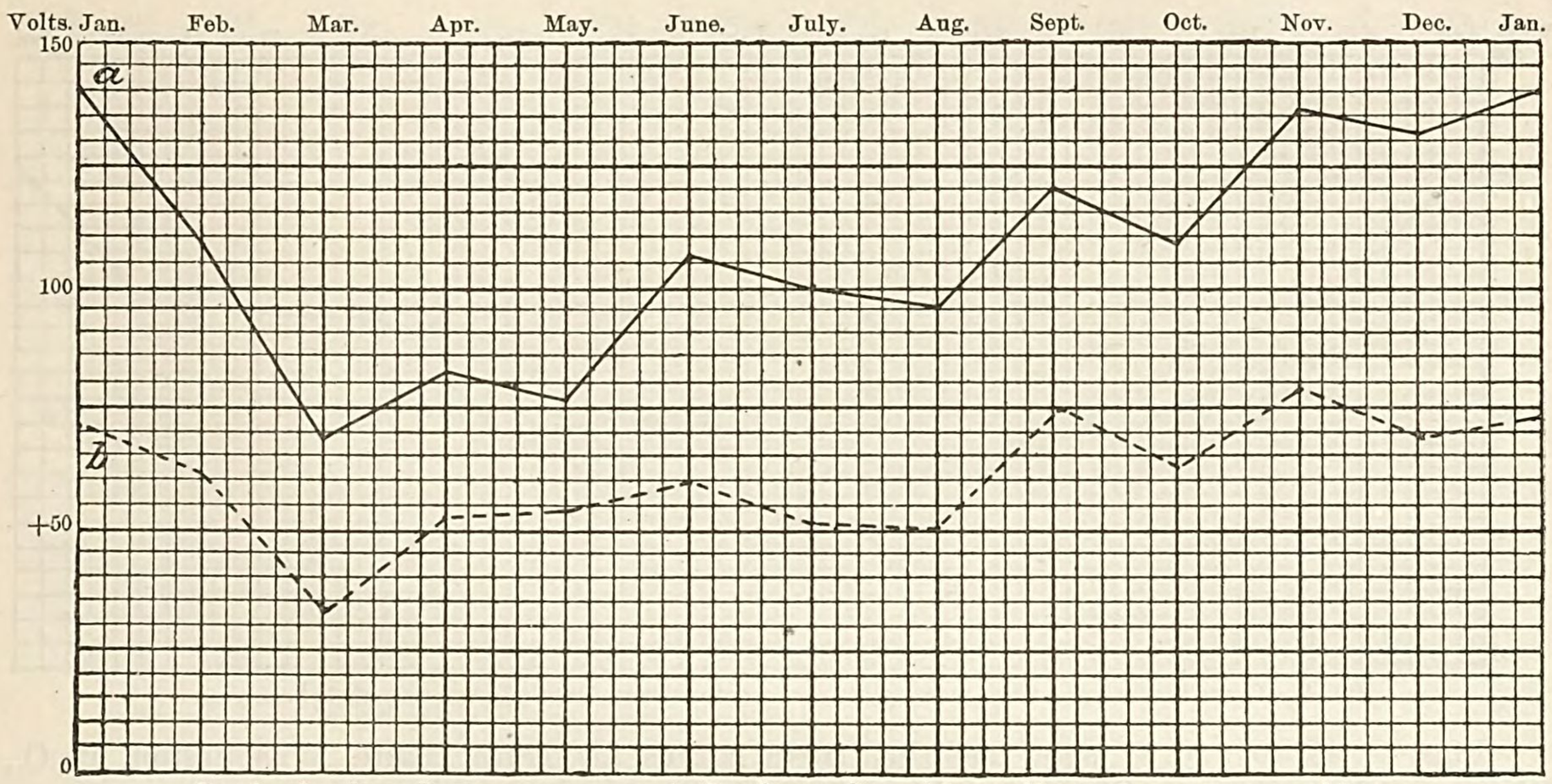
FIG. 41.—Curve showing the variations in potential before and during a high wind, October 13, 1887, Terre Haute, Ind.

On June 7 at 5:30 p. m. the potential fell from +43 to —173 and then rose slowly to its former value. The rise and fall occupied about 15 minutes and coincided with the appearance over the buildings to the west of a fleecy cirro-stratus cloud and its disappearance over the institute building in which the electrometer was located. Again, on June 9, the potential was positive all day up to 5 p. m. At that hour it fell from +73 to —113, then rising to +52. The sky was nearly free from clouds and the fluctuation coincided with the approach and departure of a cirro-stratus cloud, passing about 15° from the zenith. The inductive action of the cloud was plainly suggested in all of these cases.

MONTHLY AND HOURLY MEAN POTENTIALS.

The observations at all of the stations, except Baltimore, being rarely continuous throughout day and night, the data for obtaining monthly and hourly means is not as satisfactory as could be desired. During the last year of the work five regular observations were taken each day, the hours being 9 and 11 a. m. and 1, 3, and 5 p. m. If the mean of these correctly represented the mean of a continuous series, then nothing more could be desired for the determination of monthly means. The only way of ascertaining the relation of the mean of readings at these hours to the real daily mean is by reference to the Baltimore observations. Accordingly two sets of

monthly means have been computed for that station; one based on hourly records, drawn from the photographic registration, and the other upon records at the five regular hours, drawn from the same source. Fig. 42 shows the results exhibited in an annual curve of potential, the continuous line having been constructed from hourly readings and the broken line from readings at 9 a. m., 11 a. m., 1 p. m., 3 p. m., and 5 p. m.



a: Based on hourly readings. *b:* Based on readings at 9 a. m., 11 a. m., 1 p. m., 3 p. m., and 5 p. m.

FIG. 42.—Curves showing the mean potential for each month at Baltimore, Md., for a period of thirty-one months, January, 1885, to July, 1887.

It is interesting to see that there is a fairly close agreement in the character and extent of the fluctuations, although the mean from the five observations falls considerably below that based upon hourly readings.

As the essential matter is the variation in potential and not its absolute value, it is clear that monthly means based on observations at the above hours must have considerable significance.

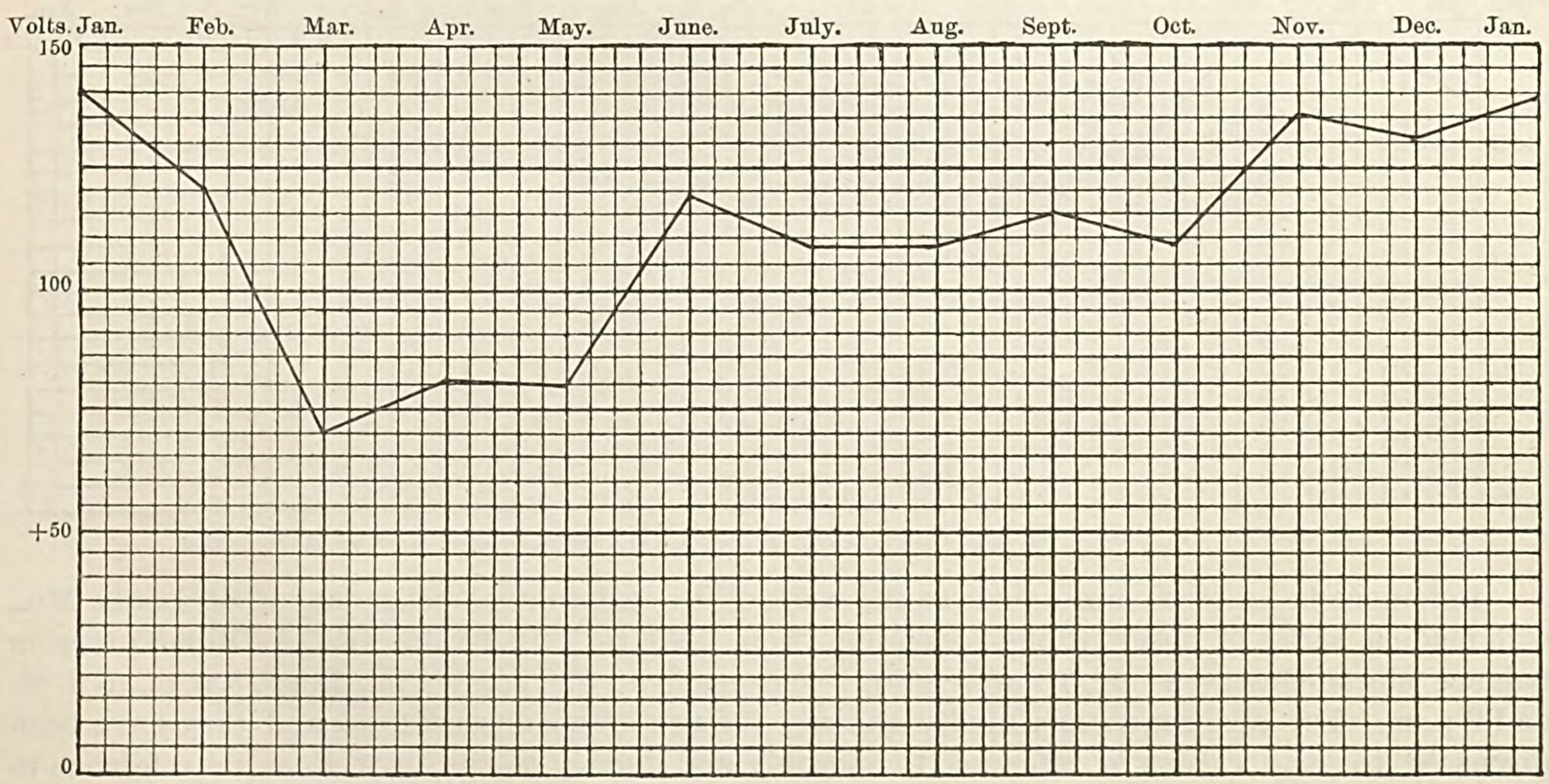


FIG. 43.—Curve showing the mean potential for each month at Baltimore, Md., excluding days on which thunderstorms occurred.

Accordingly several diagrams exhibiting these means at several stations have been prepared. Fig. 43 shows the monthly means for Baltimore after excluding from the records those belonging

to days on which thunder storms occurred. Thunder storms are always accompanied by extreme electrical activity with large range of potential, but since positive and negative deflections are generally about equal in number and magnitude, the effect on the monthly mean is not large, especially where observations are continuous, as was the case at Baltimore. It will be seen that the two diagrams for that station do not differ greatly.

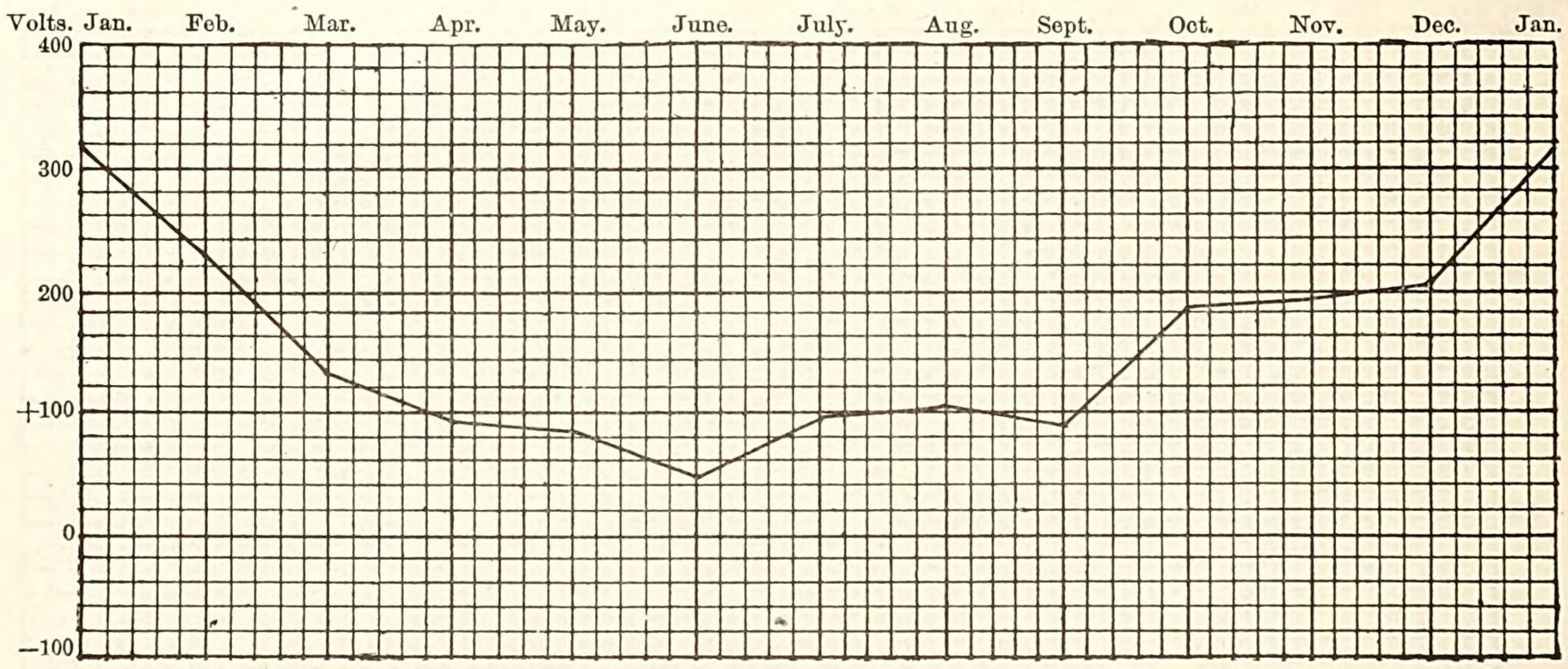


FIG. 44.—Curve showing the mean potential for each month at Terre Haute, Ind., for a period of one year.

Figs. 44, 45, 46, and 47 show monthly mean curves for Terre Haute, Washington, D. C., Ithaca, and New Haven. The first two and the last include only a single year, and that of Ithaca includes two years. The first three curves are shown in Fig. 48 and also the means of 6 months at Boston. The low potential continually recorded at New Haven makes it impossible to represent it fairly on the same scale. Terre Haute and Washington agree very fairly in the general form of the diagrams, and that for Ithaca is not greatly different except in the wider fluctuation from January to May and the extremely low potential during April, the minimum occurring in that month. During April at that station negative electricity was observed almost constantly.

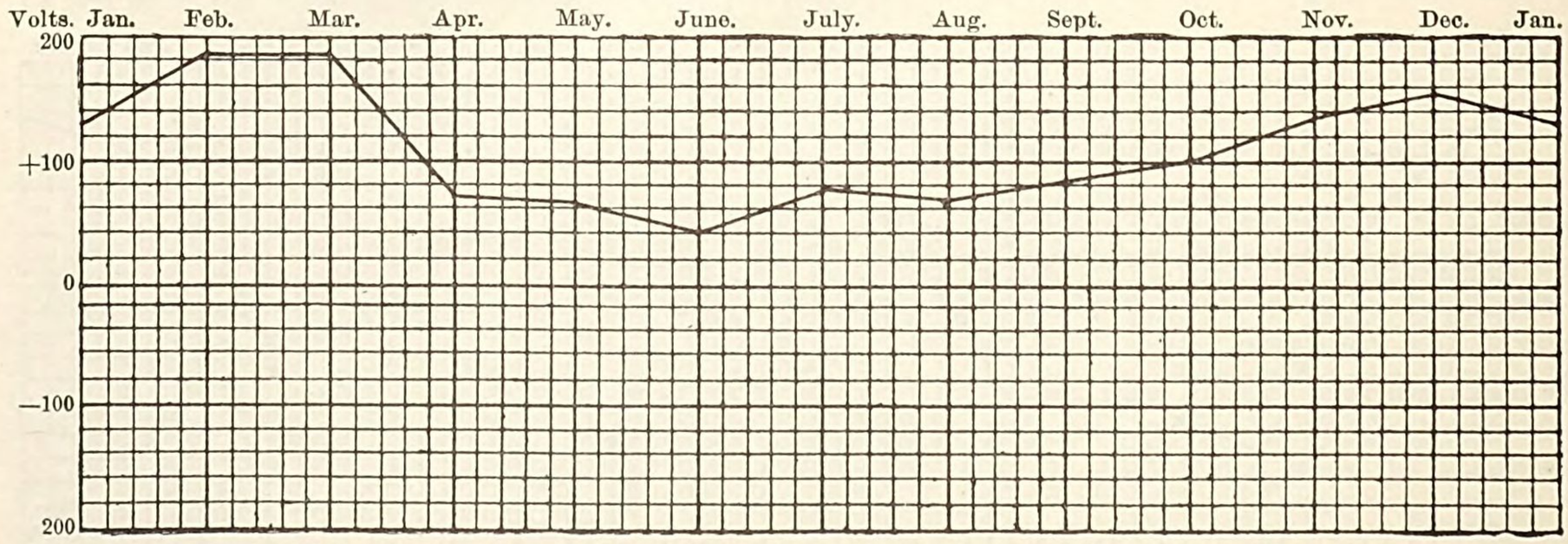


FIG. 45.—Curve showing the mean potential for each month at Washington, D. C., for a period of one year.

Reference has already been made to the work of Dr. Adolphus Wislizenus, of St. Louis, Mo., who made a series of observations extending from 1861 to 1872, inclusive. A Dillman torsion balance electrometer was used and readings were made at 6 a. m., 9 a. m., 12 m., 3 p. m., 6 p. m. and 9 p. m. Dr. Wislizenus has kindly allowed the use of his observations and they have been discussed to some extent in reference to monthly and hourly means, as well as in reference to weather and precipitation.

Volume II of the Transactions of the St. Louis Academy of Sciences contains the complete record for 1861, and Volume III contains a summary of the records for 12 years. In 1888

Prof. Francis E. Nipher, of Washington University, St. Louis, calibrated the electrometer used by Dr. Wislizenus and published his results in the Transactions of the St. Louis Academy for that year. The readings have therefore been reduced to volts by means of Professor Nipher's calibration. Fig. 49 shows two monthly mean curves for St. Louis, based upon these observations, one of which represents the means for a period of 12 years, and the other for the year 1861.

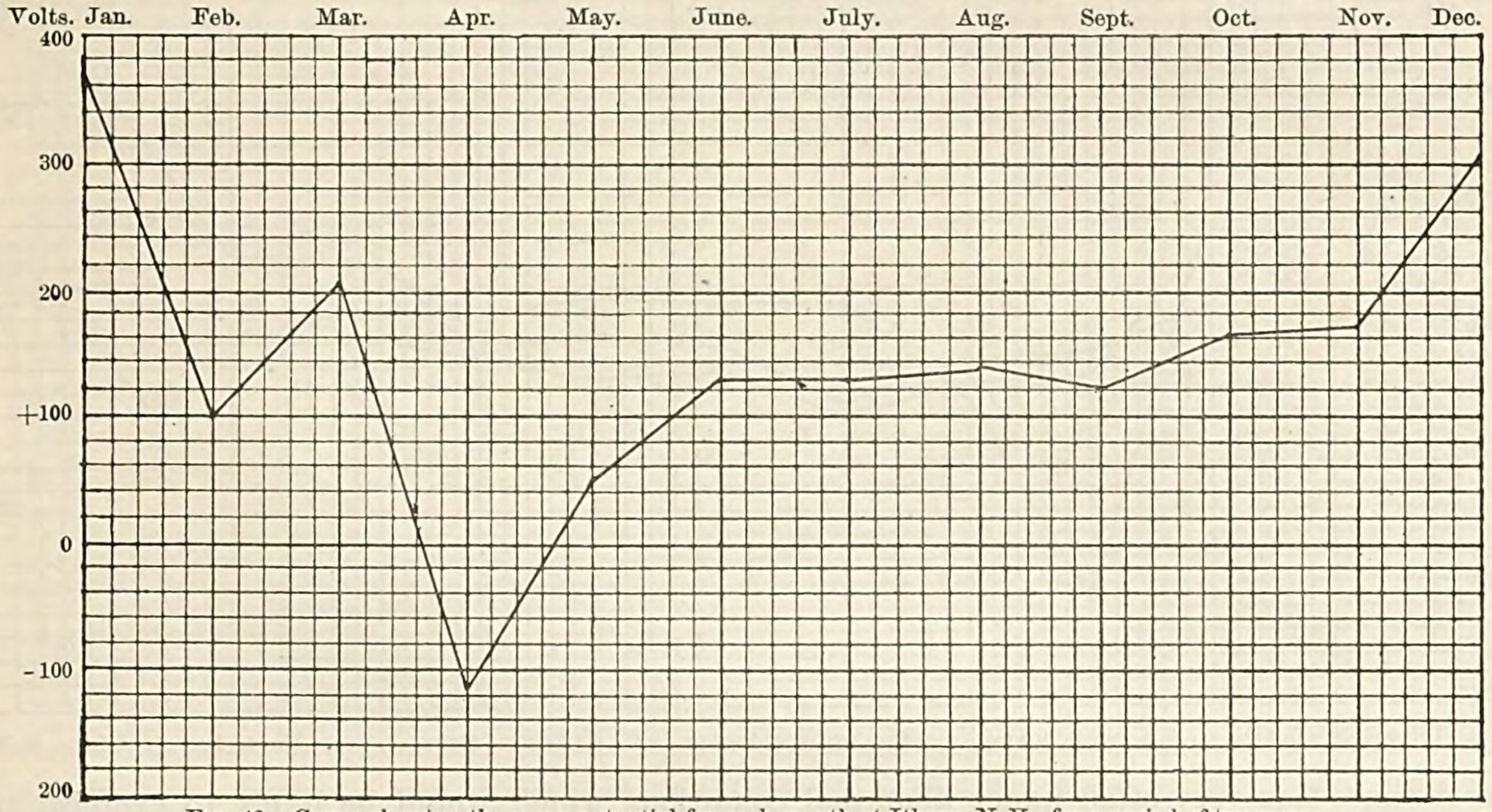


FIG. 46.—Curve showing the mean potential for each month at Ithaca, N. Y., for a period of two years.

Through the kindness of Professor Christie, Astronomer Royal of Great Britain, the published records of work in atmospheric electricity at the Kew Observatory have been received, and they have been analyzed in reference to some points considered in this report. A Thomson quadrant electrometer with self-registering attachment is in use, with a water-dropping collector. The results examined are for observations extending from 1879 to 1886 inclusive.

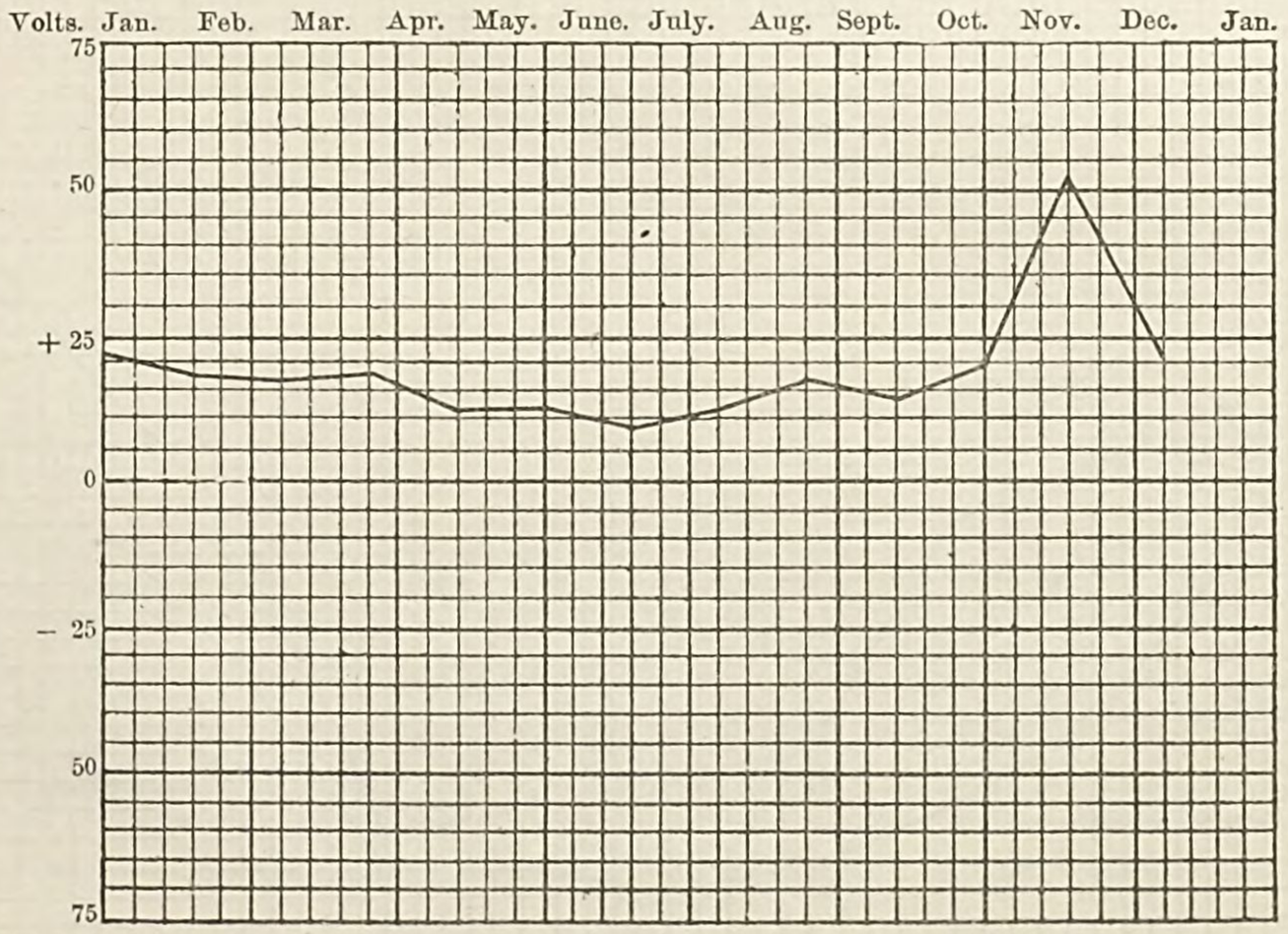


FIG. 47.—Curve showing the mean potential for each month at New Haven, Conn., for a period of one year.

In these records an arbitrary scale is employed. The monthly means for this period of 8 years are shown in Fig. 50, while the means based on observations during 2 years, 1885 and 1886, are shown in Fig. 51.

The determination of the diurnal potential curve requires, of course, a large number of observations at short intervals extending through the entire day, and it is only at Baltimore that a sufficient number are available. Series of continuous observations at other stations were made

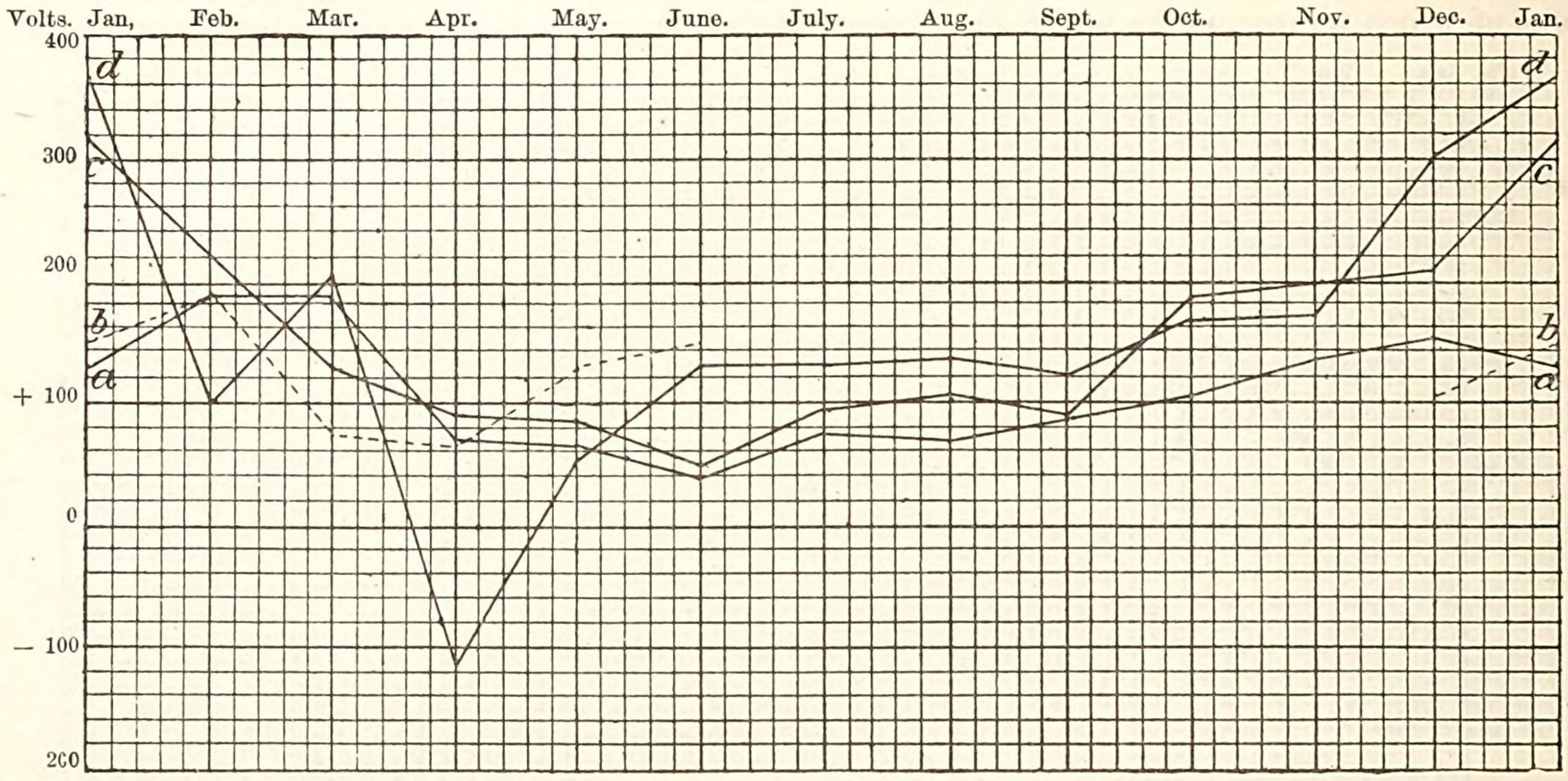


FIG. 48.—Curves showing the mean potential for each month at (*a*) Washington, D. C., (*b*) Boston, Mass., (*c*) Terre Haute, Ind., (*d*) Ithaca, N. Y.

several times but very often under abnormal conditions which would be likely to exercise an undue influence over the result. Hourly means have been computed for every hour of the day at Baltimore and for the regular hours of observation at other stations. In making these reductions it

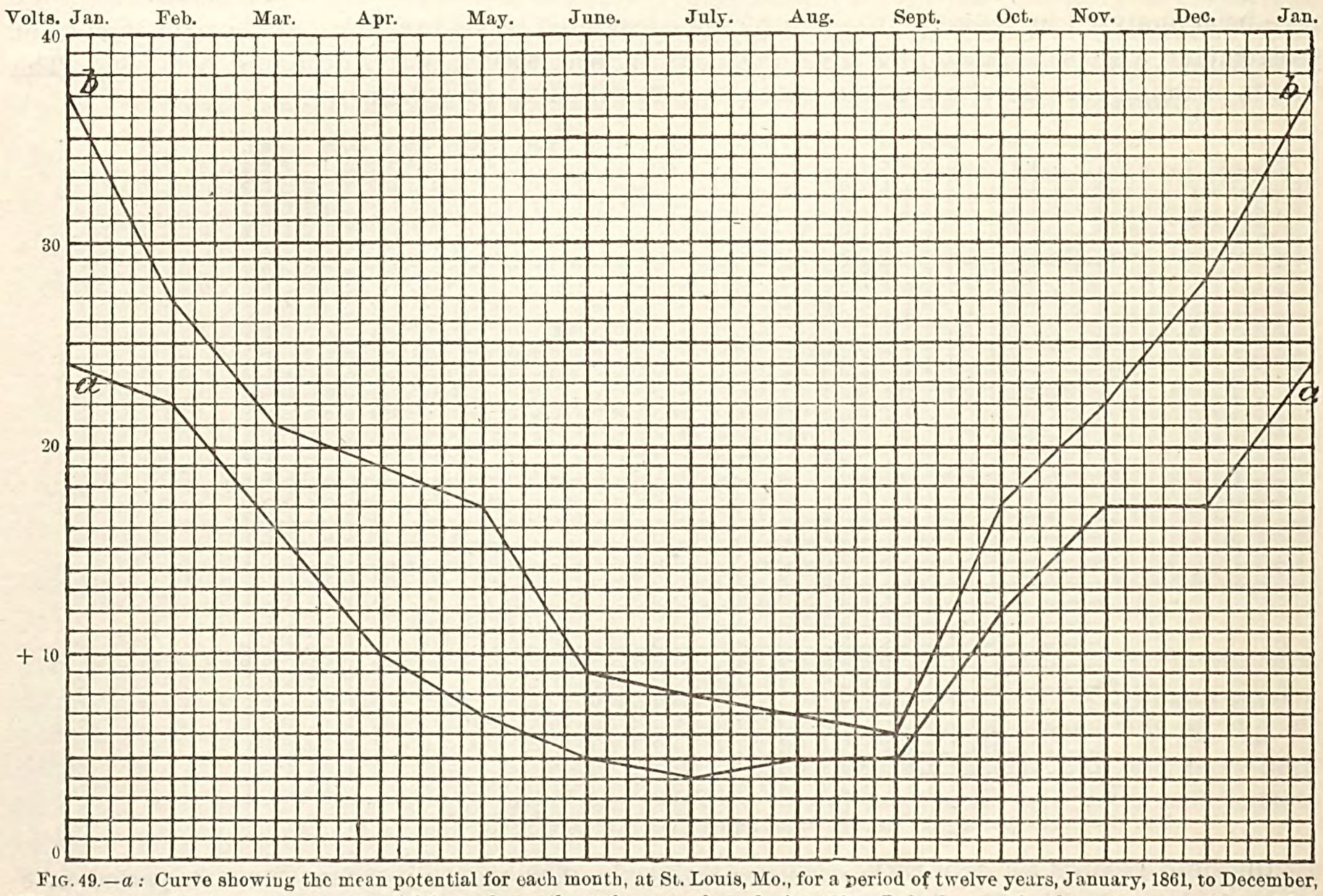


FIG. 49.—*a*: Curve showing the mean potential for each month, at St. Louis, Mo., for a period of twelve years, January, 1861, to December, 1872. *b*: Curve showing the mean potential for each month, at the same place, during 1861. In both cases the observations are those of Dr. A. Wislizenus.

has been thought desirable to eliminate the undue influence of certain months of the year in which potentials were abnormally high, and this has been done by first regarding the mean potential for each month as the unit and then computing the mean of these results for each hour for all of the months included. The numbers thus obtained indicate ratio variations above and below the mean

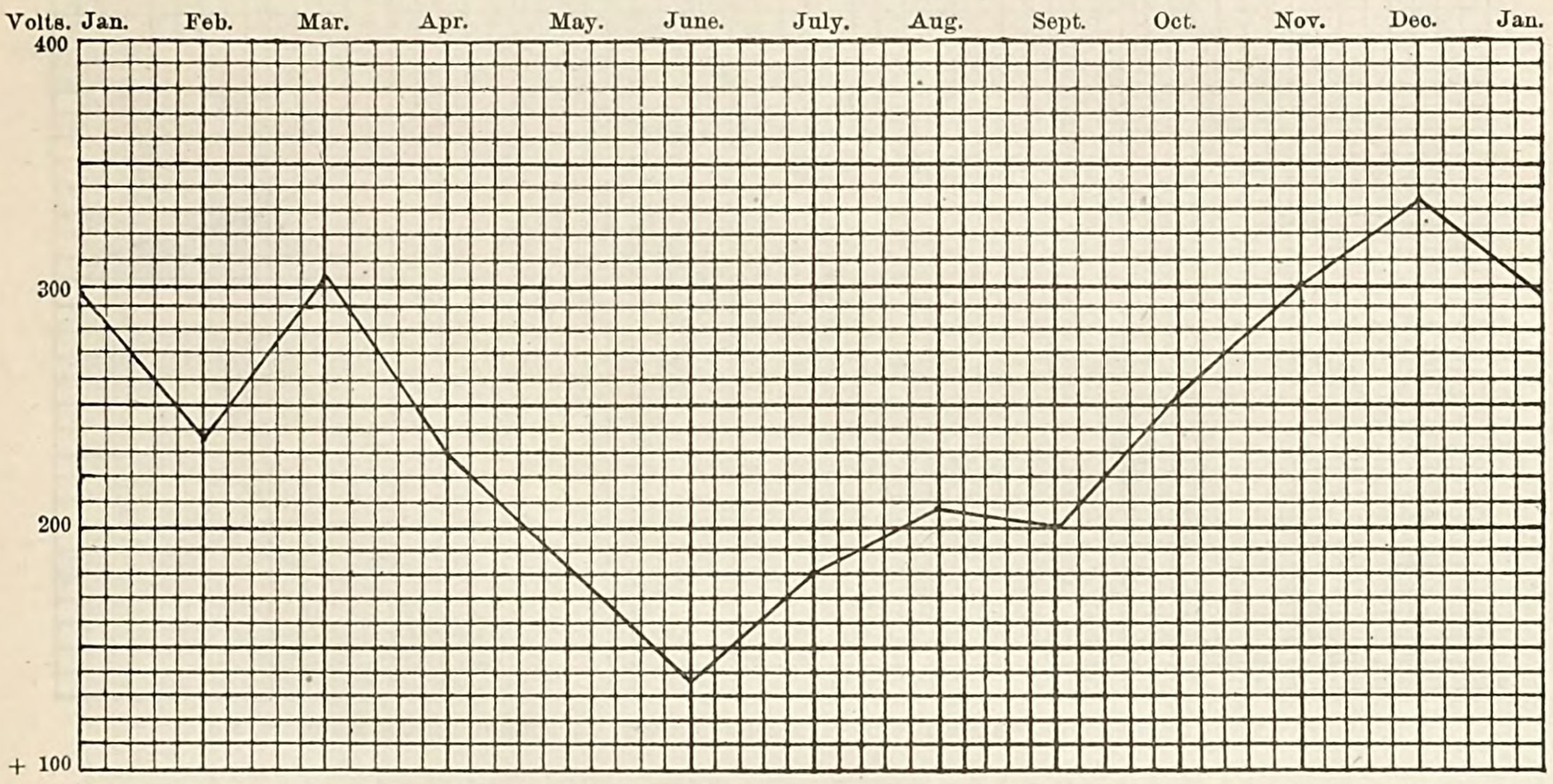


FIG. 50—Curve showing the mean potential for each month for a period of eight years, 1879-'86 (both included), at Kew Observatory, Greenwich, England. The scale is arbitrary.

and are converted into absolute potentials in volts by multiplying by the mean value. In most cases, and especially where a large number of observations is available, they do not differ greatly from a simple mean of hourly observations.

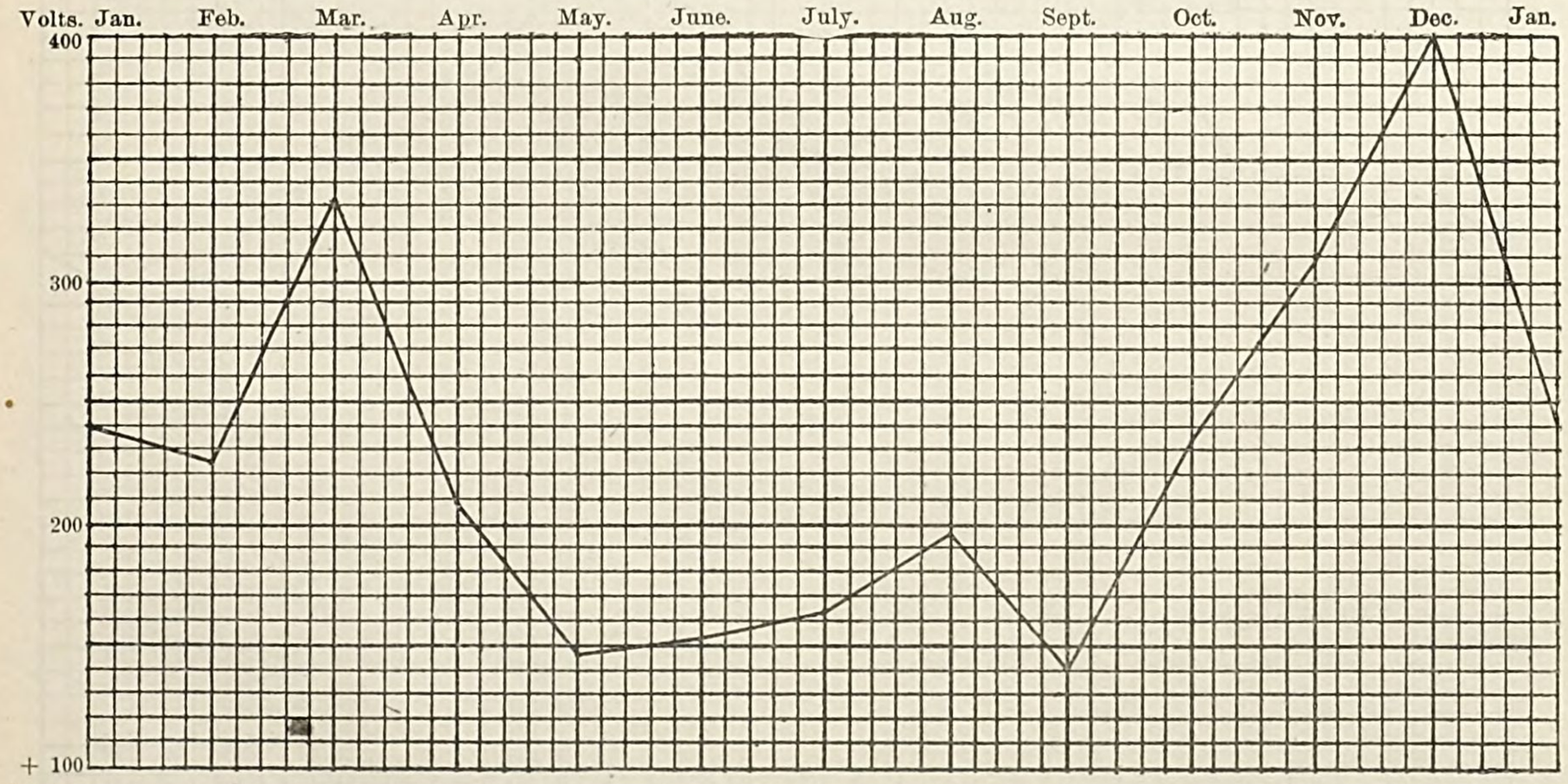


FIG. 51.—Curve showing the mean potential for each month at Greenwich, England, for a period of two years (1885-'86). The scale is arbitrary.

Fig. 52 shows hourly means for Baltimore, including all days on which registration was made, the total time covered being nearly 3 years, while Fig. 53 shows means when only clear and fair days were used. About 200 days in all are included.

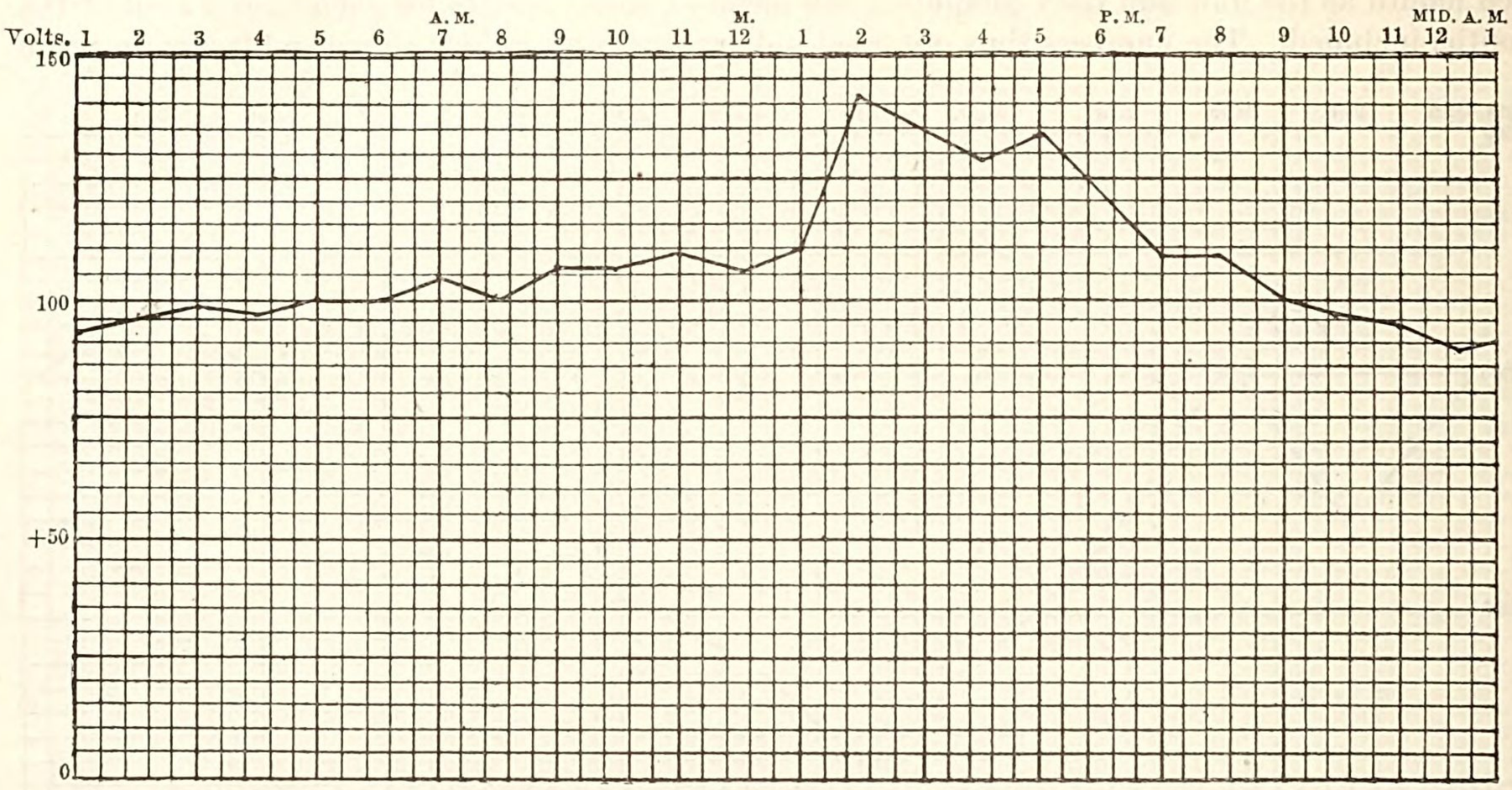


FIG. 52.—Curve showing the mean potential for each hour of the day, including all days, at Baltimore, Md.

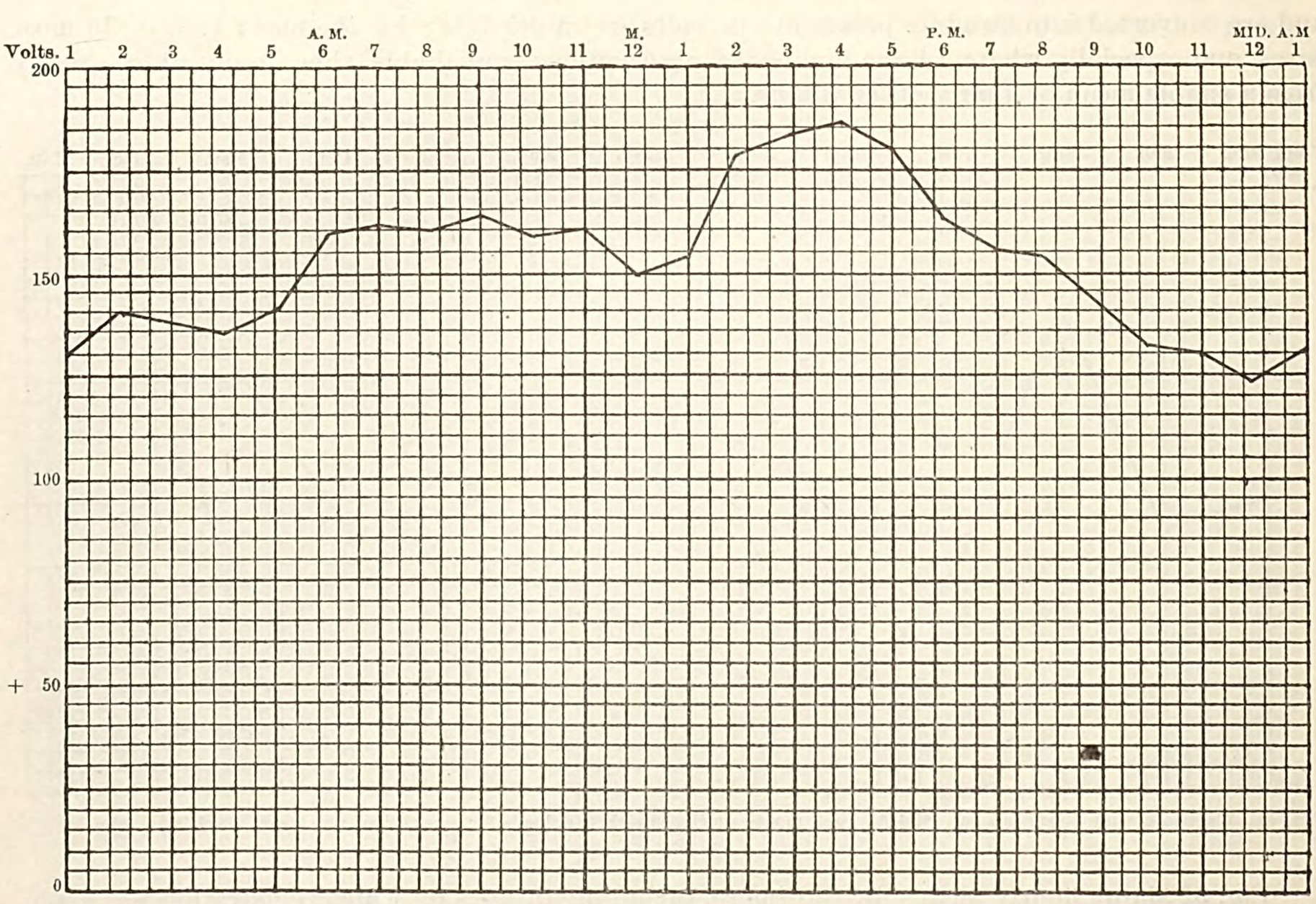


FIG. 53.—Curve showing the mean potential for each hour, on clear and fair days, at Baltimore, Md.

Figs. 54 and 55 show similar curves for Ithaca. The whole time is divided into two periods and each is represented on the diagram. The separation has been made because of the fact that exposures quite different were in use during the two periods. Figs. 56 and 57 show hourly means for the 4 stations at which observations were made during the last year of the work, and Figs. 58 and 59 show similar curves for New Haven.

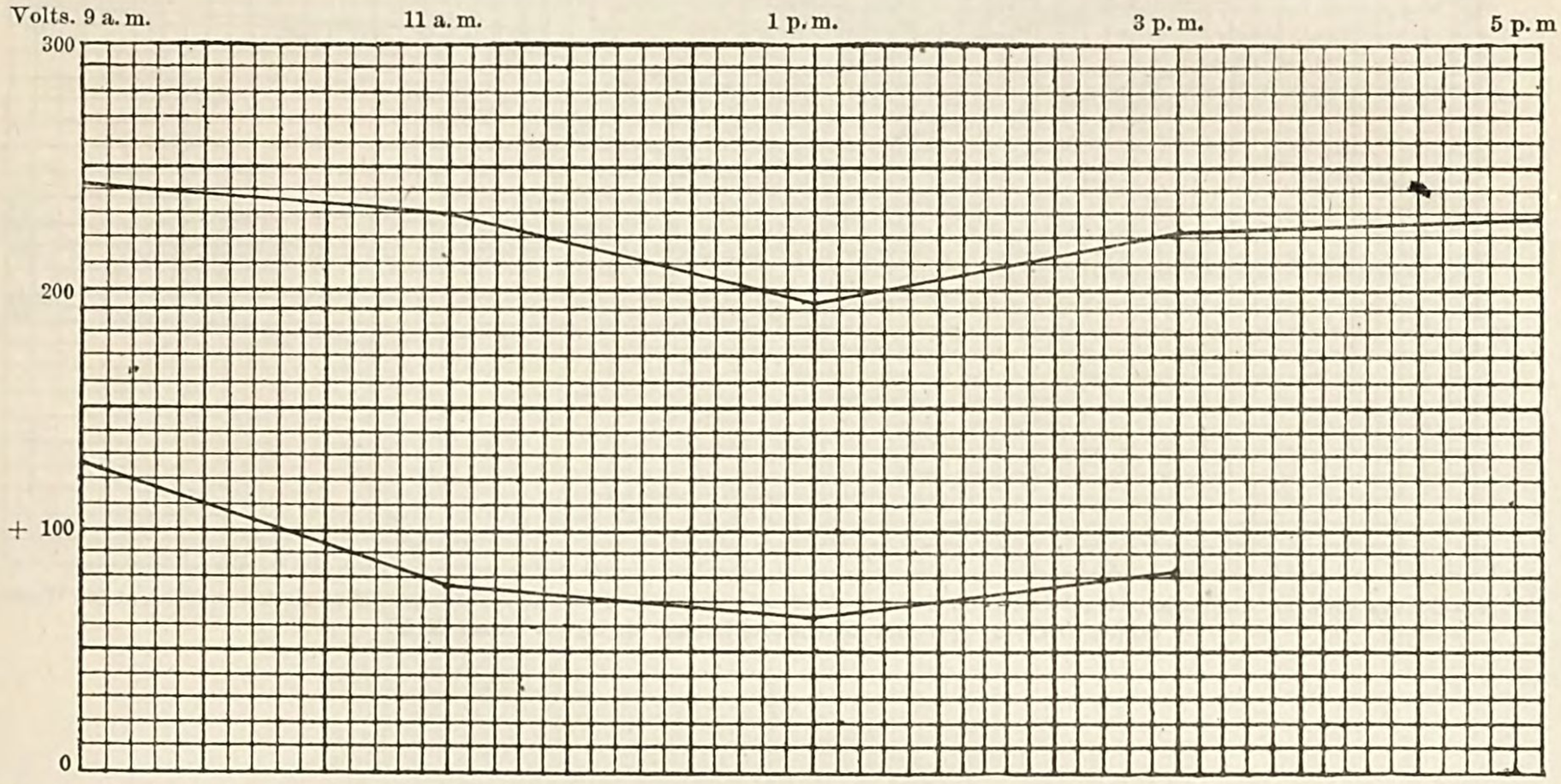


FIG. 54.—Curves showing the mean potential at each hour of observation, including all days, Ithaca, N. Y., (I) July, 1886, to September, 1887; (II) October, 1887, to August, 1888.

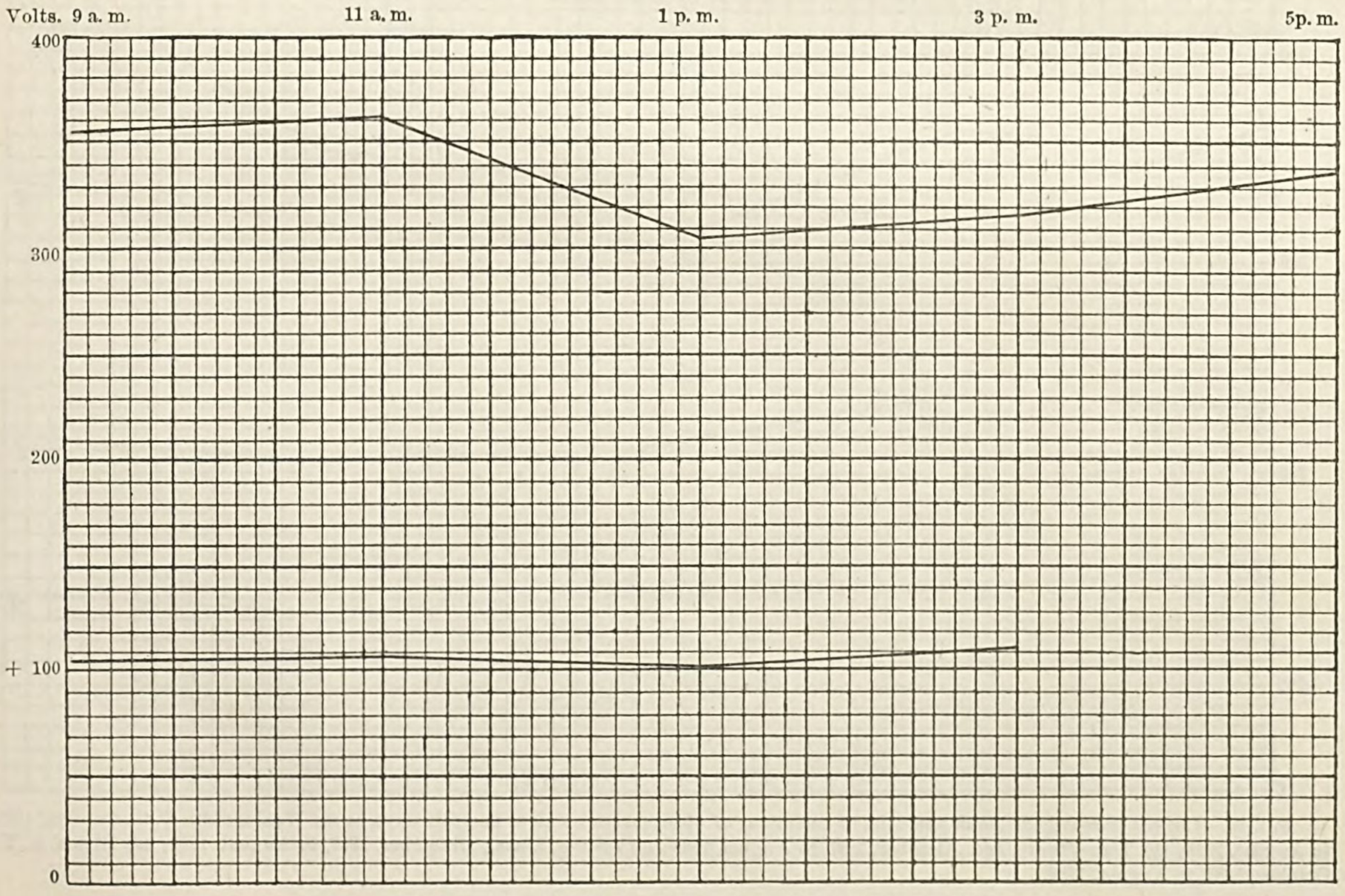


FIG. 55.—Curves showing the mean potential at each hour of observation, on clear and fair days, at Ithaca, N. Y., (I) July, 1886, to September, 1887; (II) October, 1887, to August, 1888.

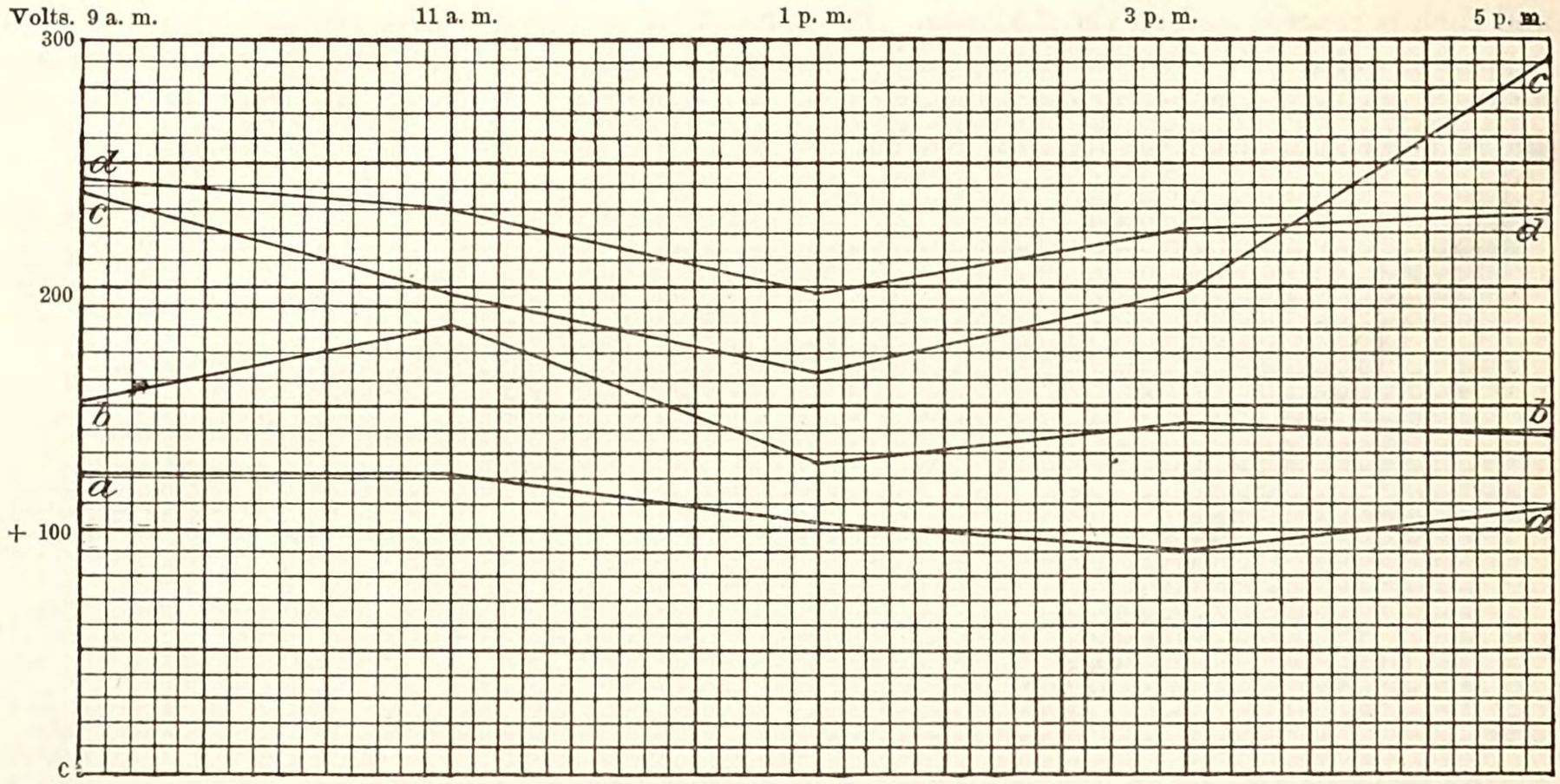


FIG. 56.—Curves showing the mean potential at each hour of observation, including all days, for a period of eleven months, at (*a*) Washington, D. C., (*b*) Terre Haute, Ind., (*c*) Boston, Mass., (*d*) Ithaca, N. Y.

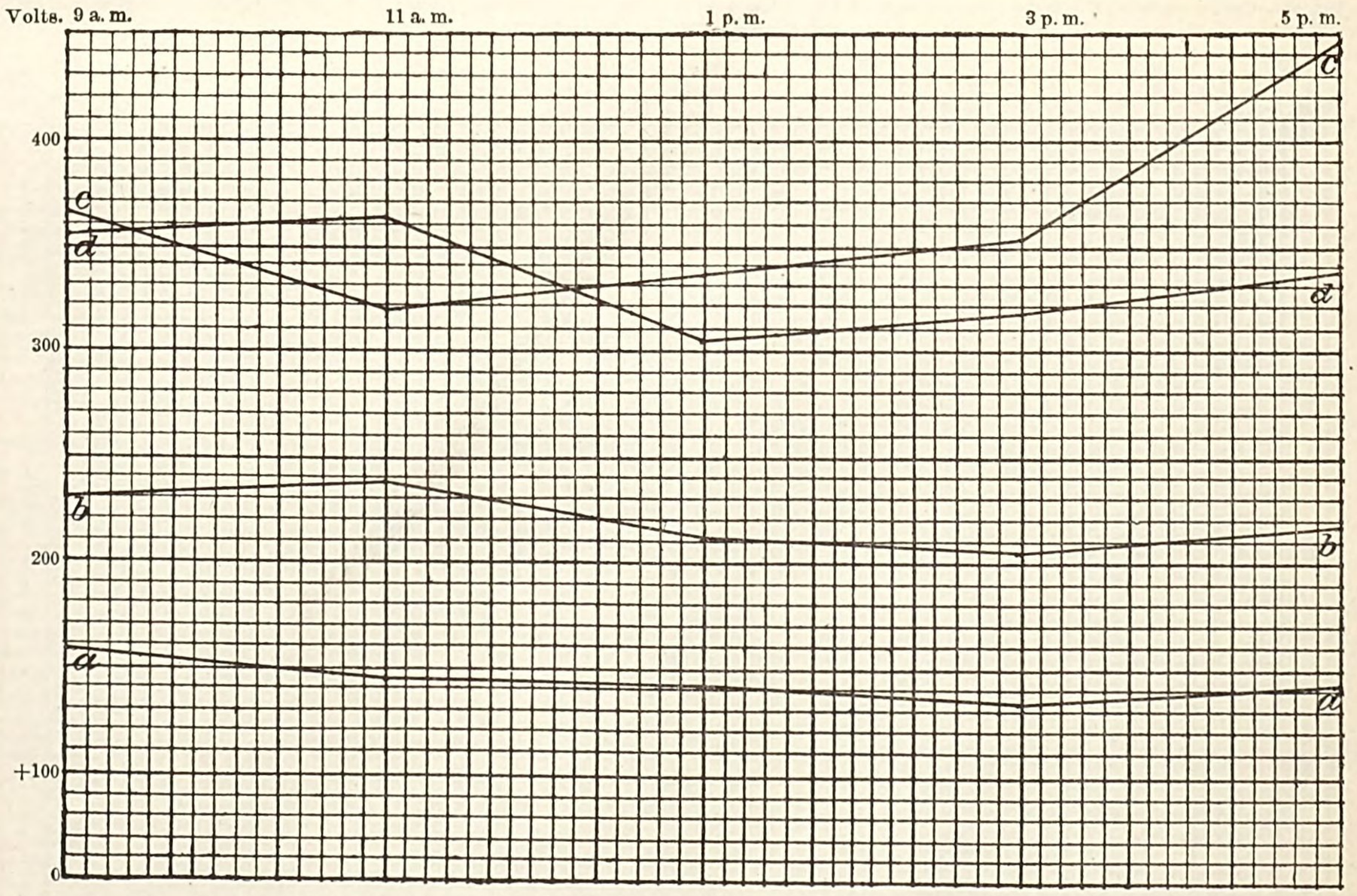


FIG. 57.—Curves showing the mean potential at each hour of observation, on clear and fair days, at (*a*) Washington, D. C., October, 1887, to August, 1888; (*b*) Terre Haute, Ind., October, 1887, to August, 1888; (*c*) Boston, Mass., December, 1887, to August, 1888; (*d*) Ithaca, N. Y., October, 1887, to August, 1888.

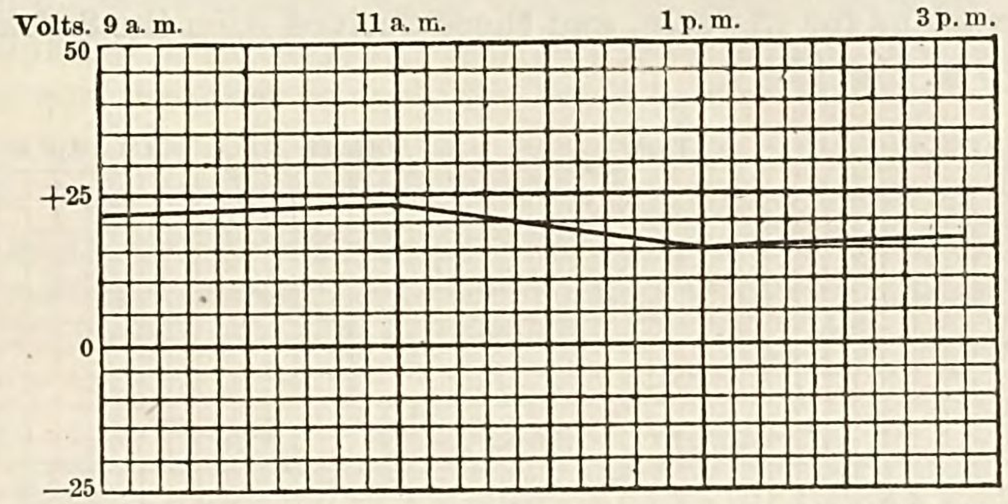


FIG. 58.—Curve showing the mean potential at each hour of observation, including all days, at New Haven, Conn., from July 30, 1886, to August 1, 1887.

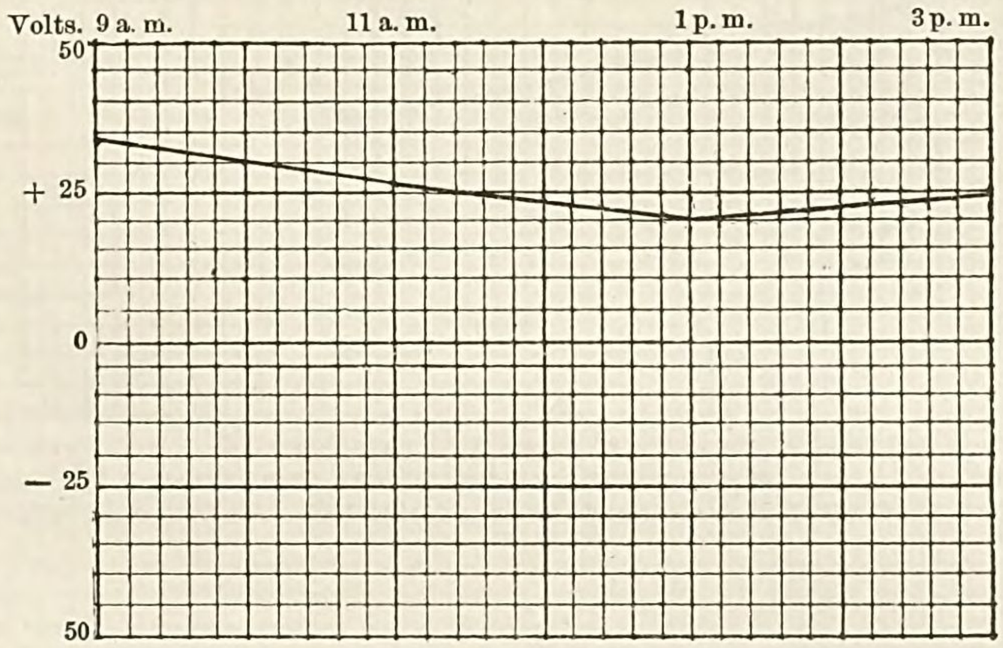


FIG. 59.—Curve showing the mean potential on clear days, at each hour of observation, at New Haven, Conn., from July 30, 1886, to August 1, 1887.

Fig. 60 shows hourly means for the St. Louis observations, the lower line representing the reduction of all observations for 12 years, and those derived from the 8 years' records of the Kew Observatory are shown in Fig. 61.

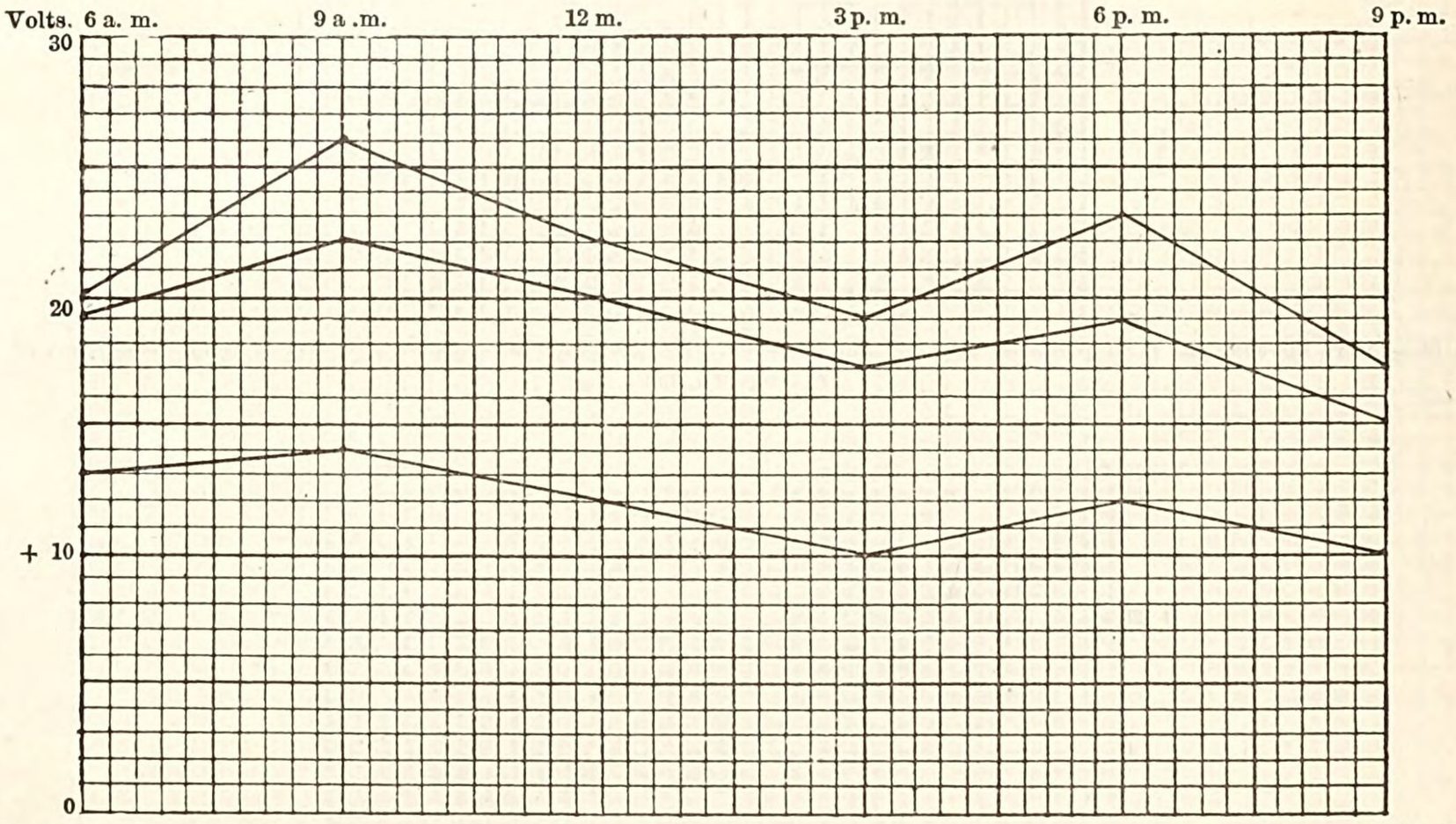


Fig. 60.—I: Curve showing mean potential at eacn hour of observation, including all days, from Januarv 1, 1861, to December 31, 1872. II: Curve showing mean potential at each hour of observation, including all days, from January 1, 1861, to December 31, 1861. III: Curve showing mean potential at each hour of observation on clear and fair days during 1861. All from observations of Dr. A. Wislezenus, at St. Louis, Mo.

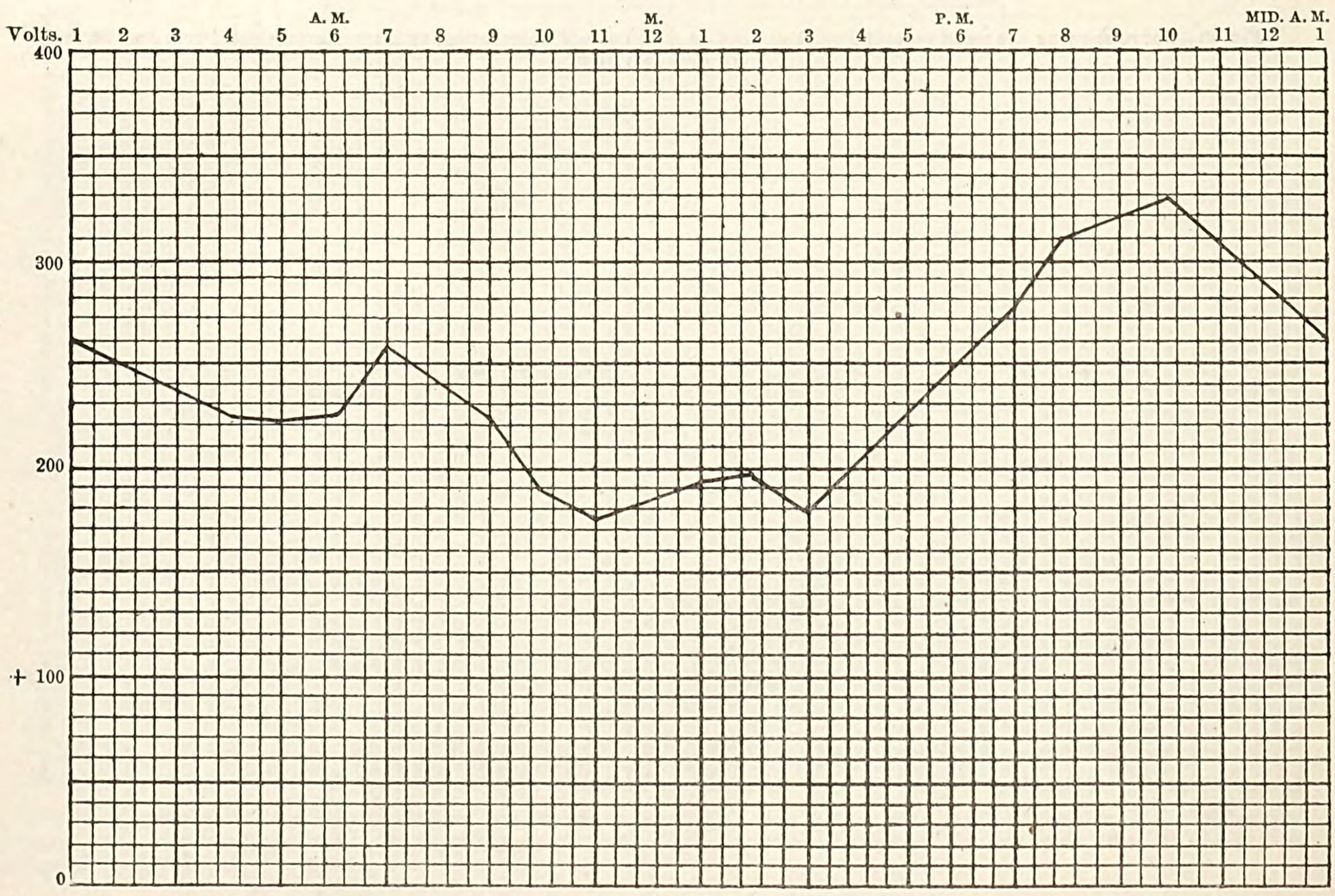


Fig. 61.—Curve showing the mean potential in arbitrary units for each hour of the day, including all days, for a period of eight years, 1879–'86 (both included), at the Kew Observatory, Greenwich, England.

Most of these results, as illustrated in the diagrams, seem to indicate the existence of two principal maxima of potential in the day, and also, in a general way, that one of these occurs not many hours before noon and the other towards the latter part of the day.

No very close agreement exists, however, and the evidence is rather in favor of the conclusion that the time at which these maxima occur depends largely on location. The observations at Baltimore, at St. Louis, and at Greenwich are, of course, the most valuable in determining this, and it will be seen that they differ materially as to the location of the maxima, although in agreement as to their existence and, in a general way, as to the part of the day in which they occur.

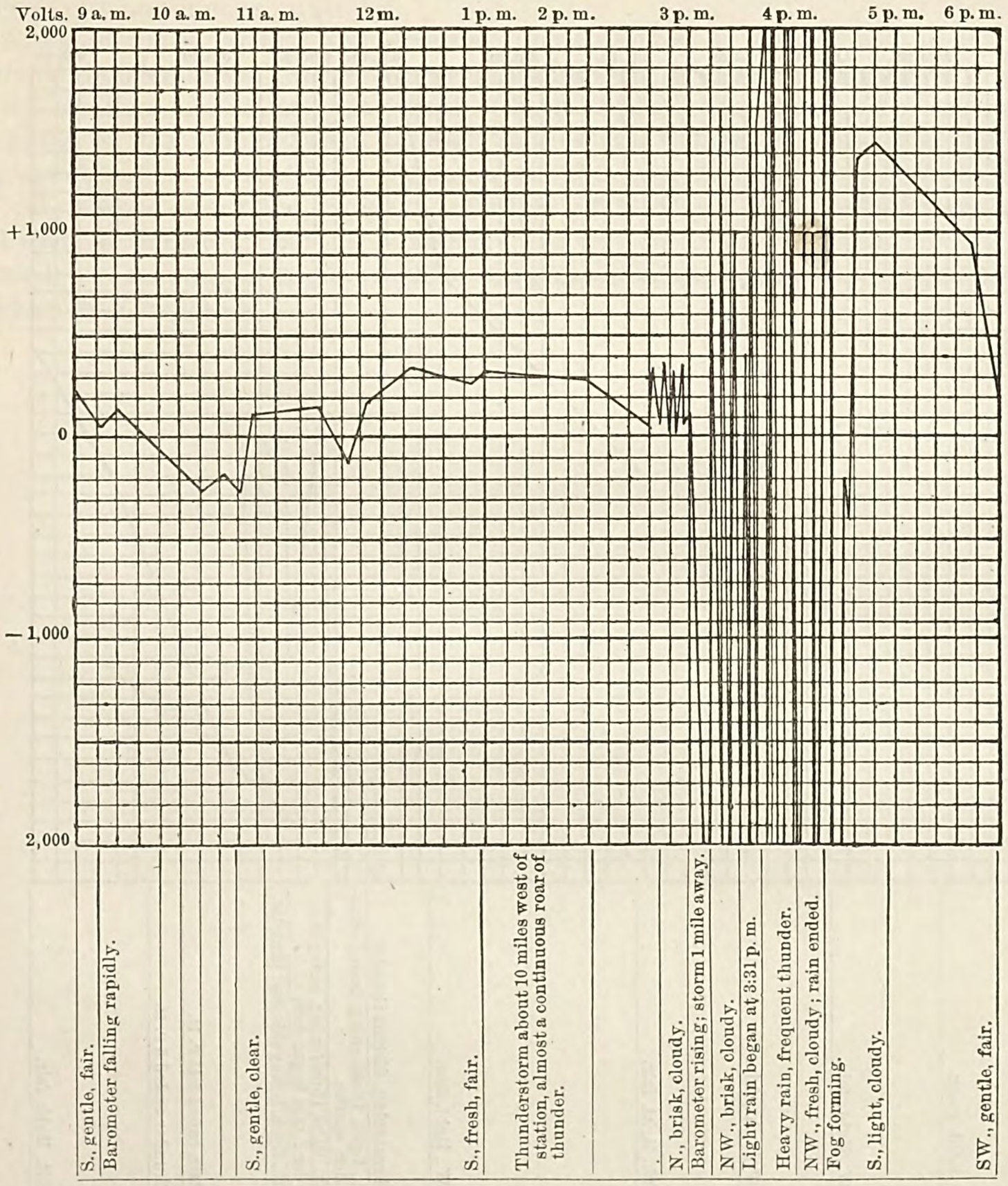


FIG. 62.—Curve showing variations of potential at Ithaca, N. Y., May 31, 1888, a day on which a thunderstorm occurred. Sparks passed from needle to quadrants almost continually from 3:15 to 4:30 p. m.

POTENTIAL DURING THUNDERSTORMS.

On many occasions special observations at short intervals were made during thunderstorms, including often some hours before and after the thunderstorm proper. The characteristic feature of the electrometer records on such occasions is the rapidity and extent of the potential fluctuations. Almost invariably the needle vibrates with unusual rapidity from side to side, going beyond the registering capacity of the instrument in both positive and negative directions, and much sparking from the needle to the quadrants usually occurs.

A good illustration of such a record is shown in Fig. 62 which exhibits the variations of potential at Ithaca on May 31, 1888, a thunderstorm occurring between 3 and 5 p. m. of that day. It will be observed that, in this instance, while the storm was raging at a distance of several miles, it produced little if any effect upon the movements of the needle. In some other cases the potential at the observing station was very materially affected when a thunderstorm was so distant that the thunder could not be heard. Fig. 63 shows observations made before, during, and after a thunderstorm at Terre Haute on July 8, 1887. Here it will be noticed that violent fluctuations occurred when the thunderstorm was distant, and that an hour later amid heavy rain and thunder at the station, the movements of the needle were comparatively moderate. The diagrams showing

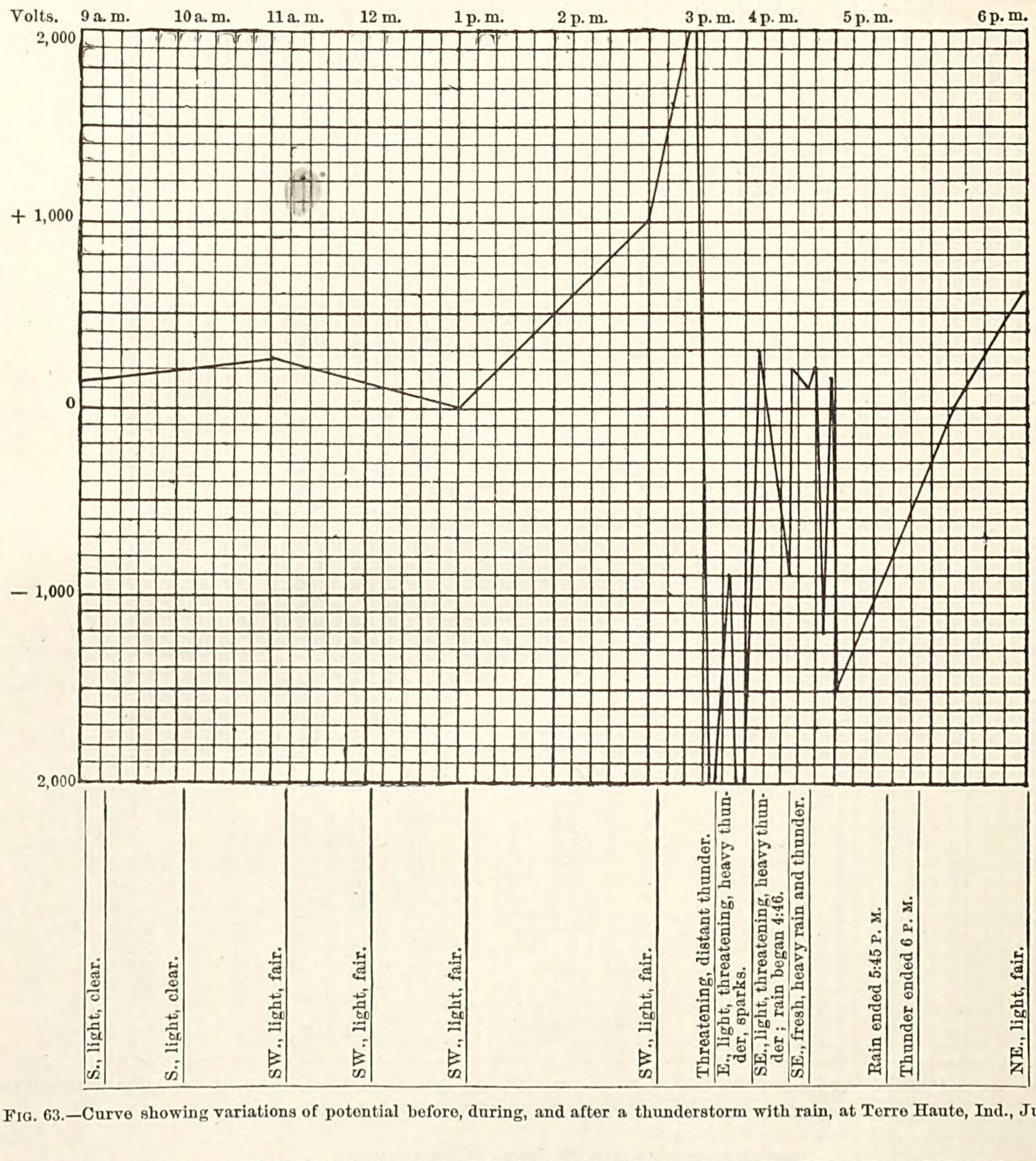


FIG. 63.—Curve showing variations of potential before, during, and after a thunderstorm with rain, at Terre Haute, Ind., July 8, 1887.

potential variations at Baltimore during thunderstorm days are reduced copies of the photographic records and have been selected from a large number as fairly representing the whole collection.

Aside from the general characteristics already mentioned, the rapidity and range of fluctuation, these potential curves seem to have little in common.

The examination of a few cases only might lead to interesting conclusions, which would almost certainly be overthrown by the study of a greater number.

Sometimes the potential falls rather steadily until the violent movements begin, but sometimes it rises just as long and steadily. In many cases the violent fluctuations start from a high positive, while in many others the reverse is the case. The storm is usually accompanied by precipitation; sometimes this begins before the needle starts on its series of swings from side to side, and sometimes these movements precede precipitation. The steady rise in potential for some hours immediately following a thunderstorm may mean that clear and fair weather is to be expected.

Fig. 71, showing the curve for September 19, 1886, is good evidence that it may also be interpreted to mean that another thunderstorm is just at hand. The diagrams, May 7, 8, and 9, 1887 (Figs. 72 and 73), are interesting as showing a series of thunderstorms occurring as parts or elements of a continuous rainstorm.

Although these records are somewhat unsatisfactory as far as throwing any light upon the nature of thunderstorms, it must not be forgotten that, with the exception of a single instance already mentioned, a set of simultaneous observations at the Signal Office and the Smithsonian Institution at Washington, none of these storms has influenced more than one station. The complete electric investigation of the storm would demand a large number of observing stations, relatively near to each other, by means of which a full history of the potential changes about and in all parts of the storm could be obtained.

Such an examination might result in bringing order and system out of what seems at present little less than confusion.

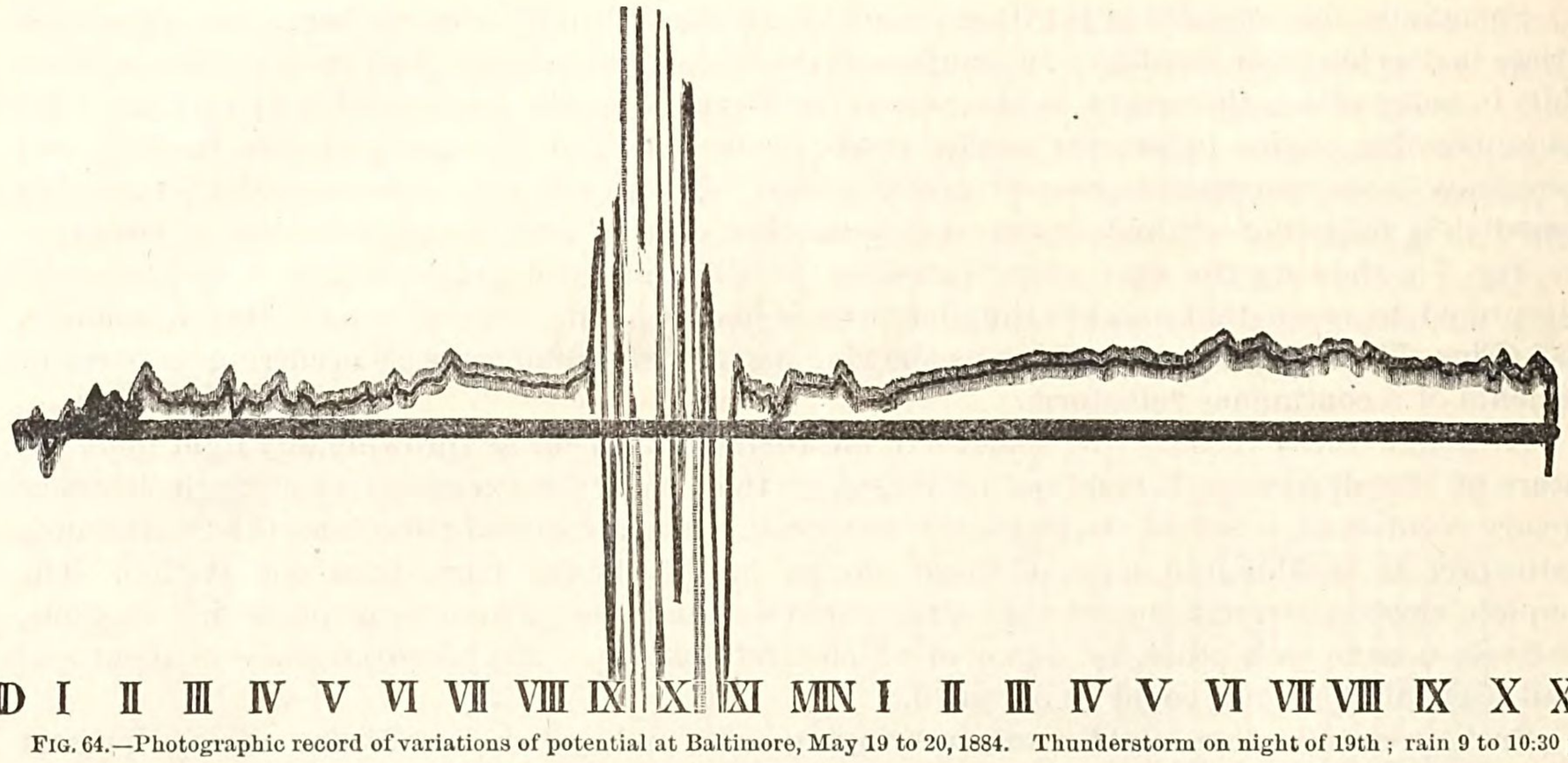


FIG. 64.—Photographic record of variations of potential at Baltimore, May 19 to 20, 1884. Thunderstorm on night of 19th; rain 9 to 10:30 p. m.

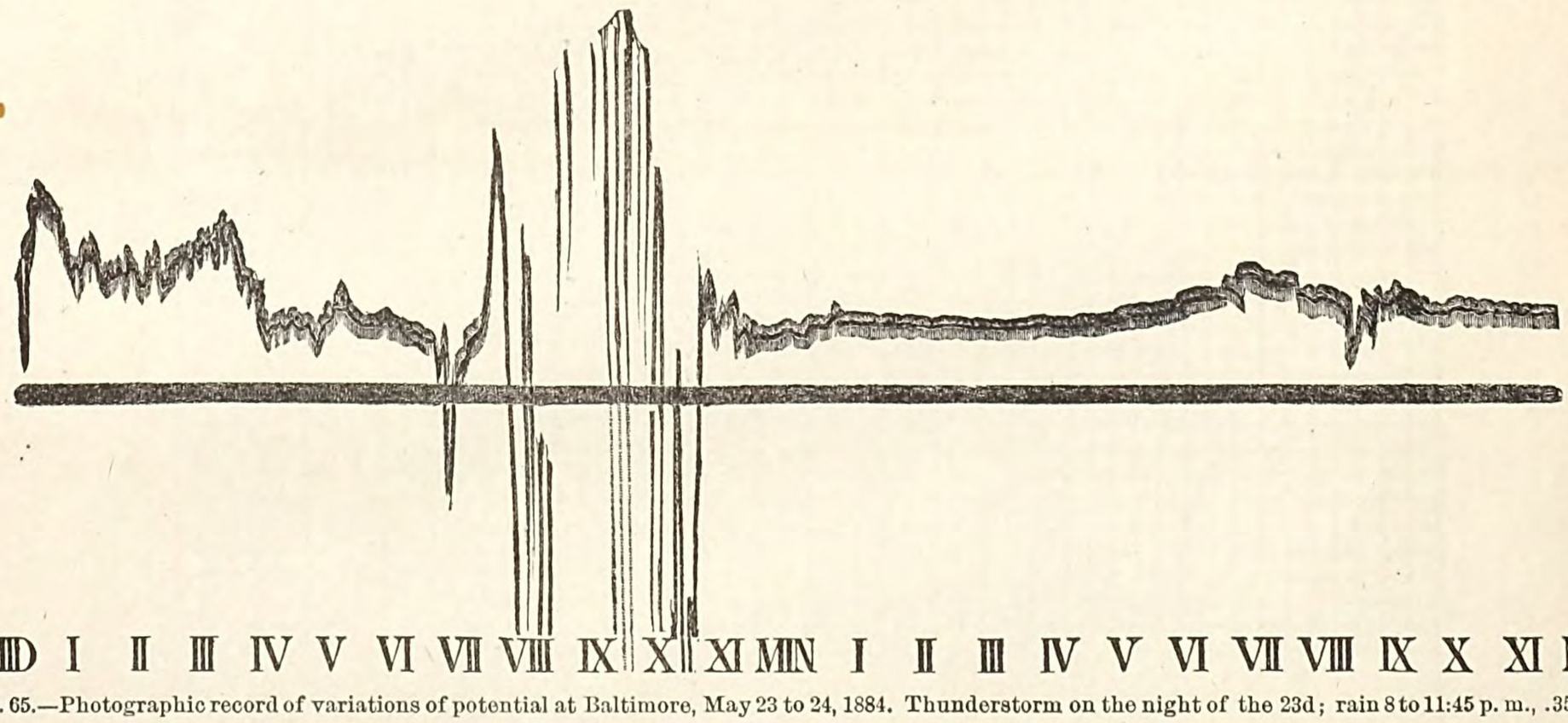


FIG. 65.—Photographic record of variations of potential at Baltimore, May 23 to 24, 1884. Thunderstorm on the night of the 23d; rain 8 to 11:45 p. m., .35 inch.

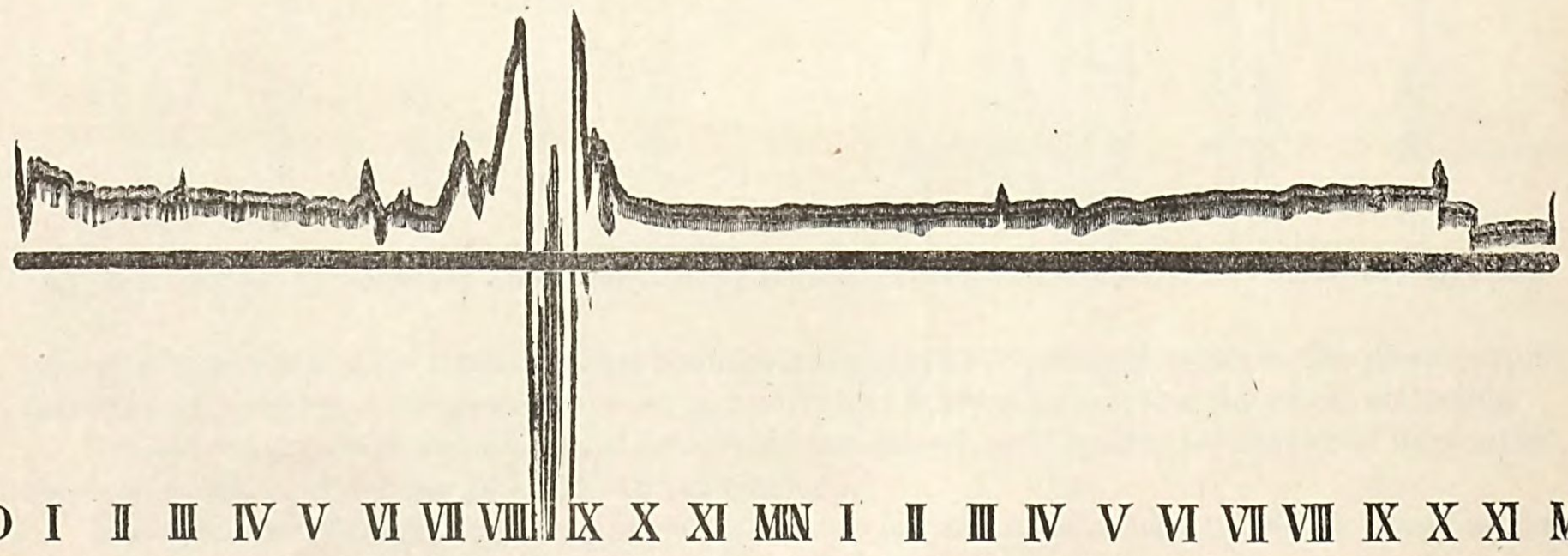


FIG. 66.—Photographic record of variations of potential at Baltimore, May 24 to 25, 1884. Thunderstorm in the evening of the 24th; rain 8:40 to 9:20 p. m.

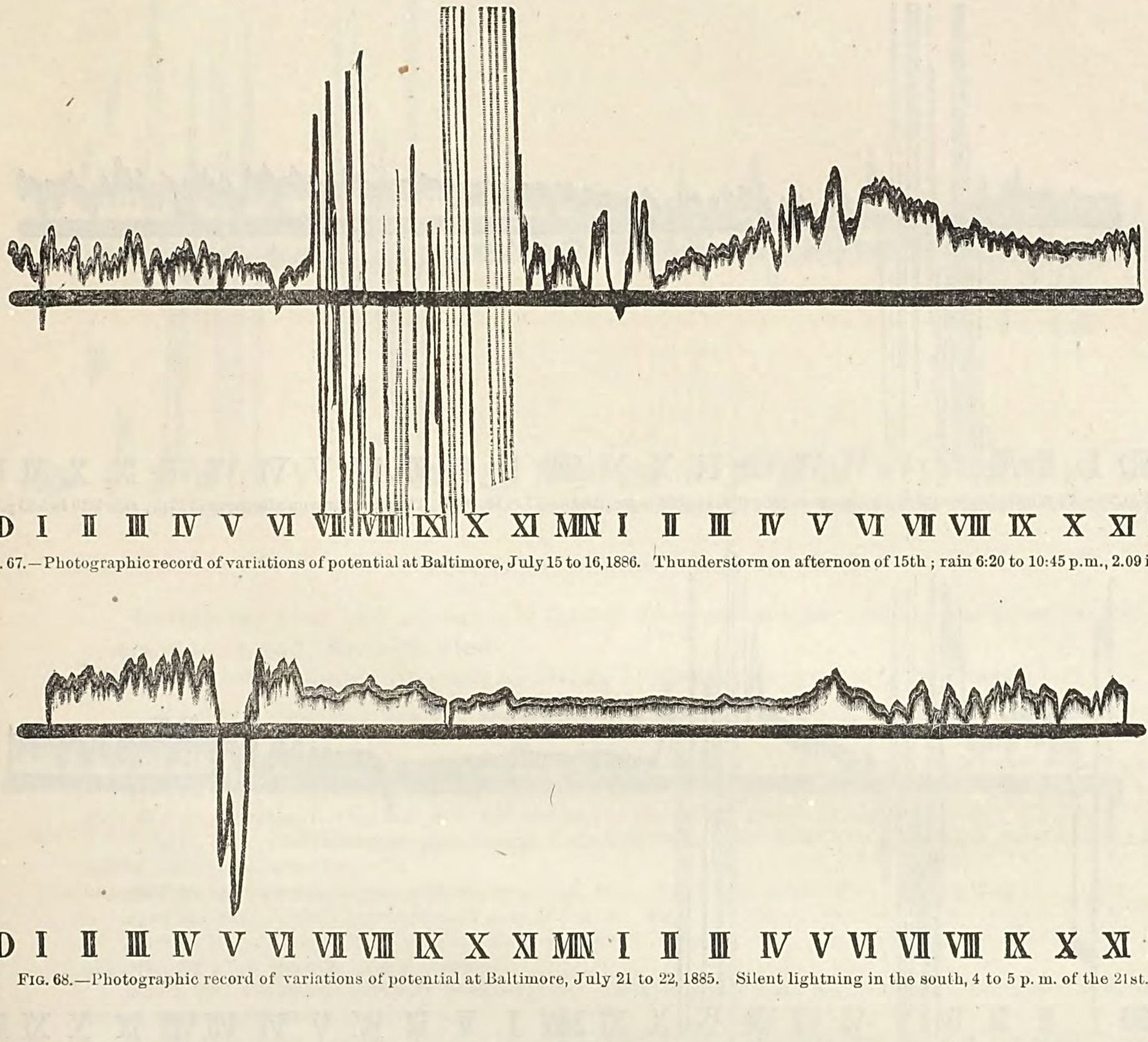


FIG. 67.—Photographic record of variations of potential at Baltimore, July 15 to 16, 1886. Thunderstorm on afternoon of 15th ; rain 6:20 to 10:45 p.m., 2.09 inches.

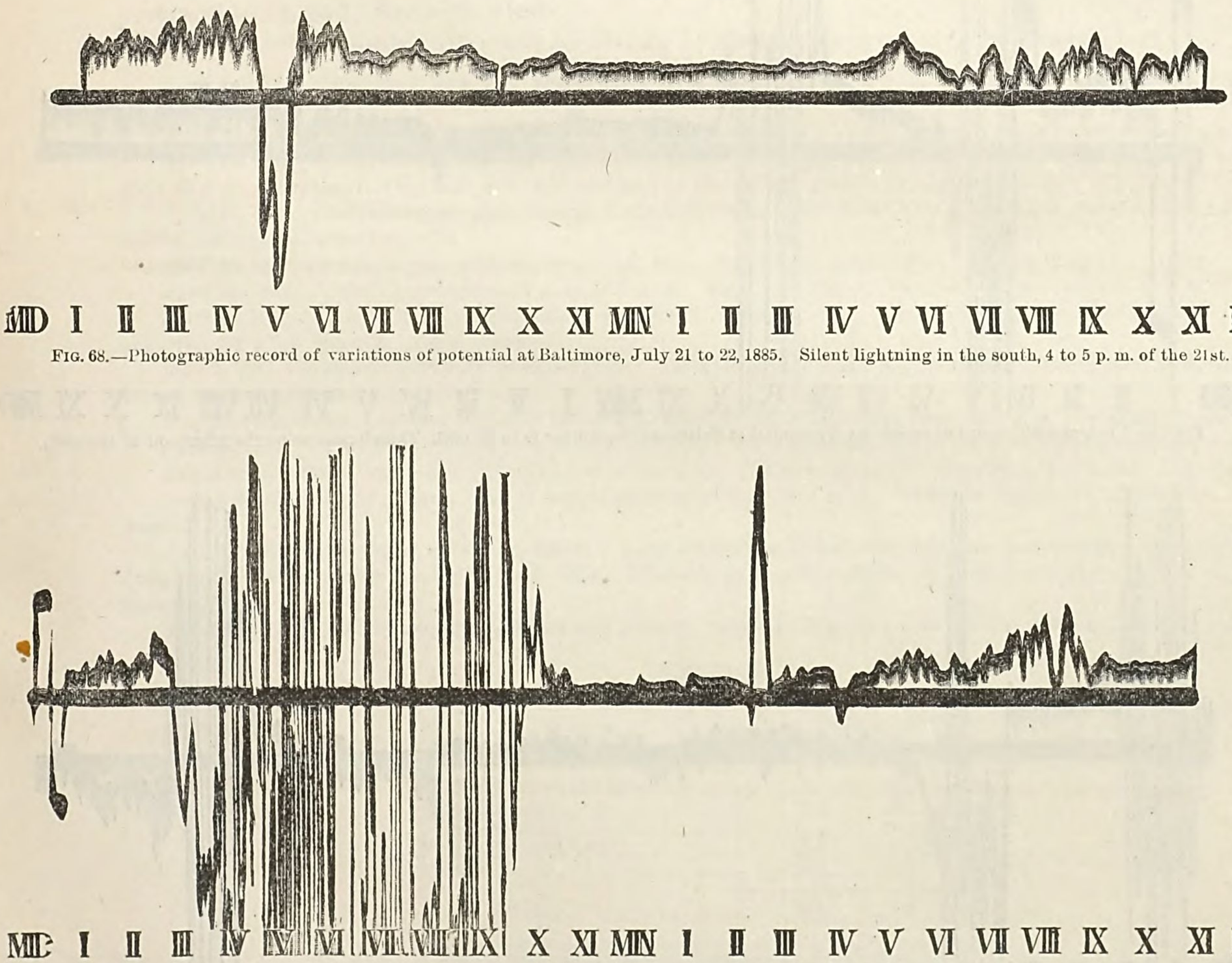


FIG. 68.—Photographic record of variations of potential at Baltimore, July 21 to 22, 1885. Silent lightning in the south, 4 to 5 p. m. of the 21st.

FIG. 69.—Photographic record of variations of potential at Baltimore, July 26 to 27, 1886. Thunderstorm on afternoon of 26th ; rain 4:30 to 11:30 p. m., 1.14 inches.

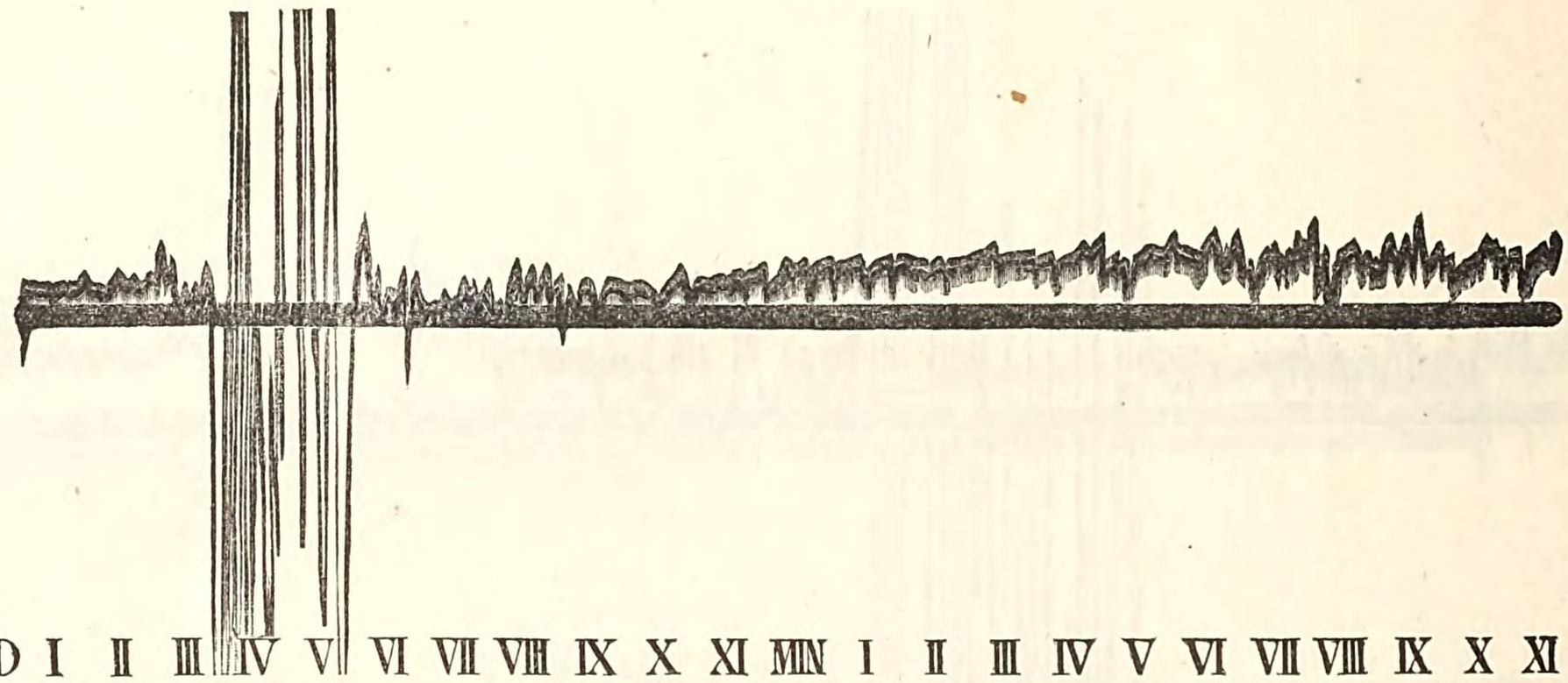


FIG. 70.—Photographic record of variations of potential at Baltimore, August 17 to 18, 1886. Thunderstorm on afternoon of 17th; rain 3:10 to 5:35 p. m.

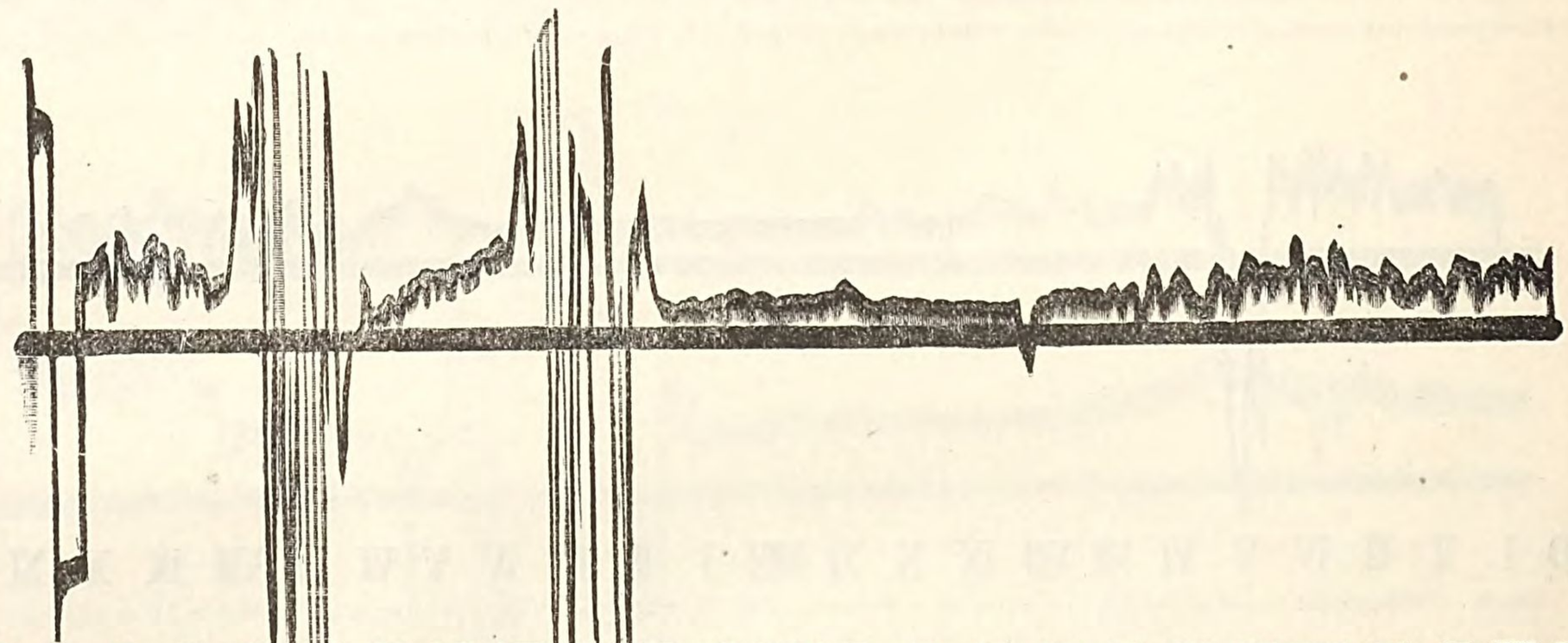


FIG. 71.—Photographic record of variations of potential at Baltimore, September 19 to 20, 1886. Thunderstorms on the afternoon of the 19th.

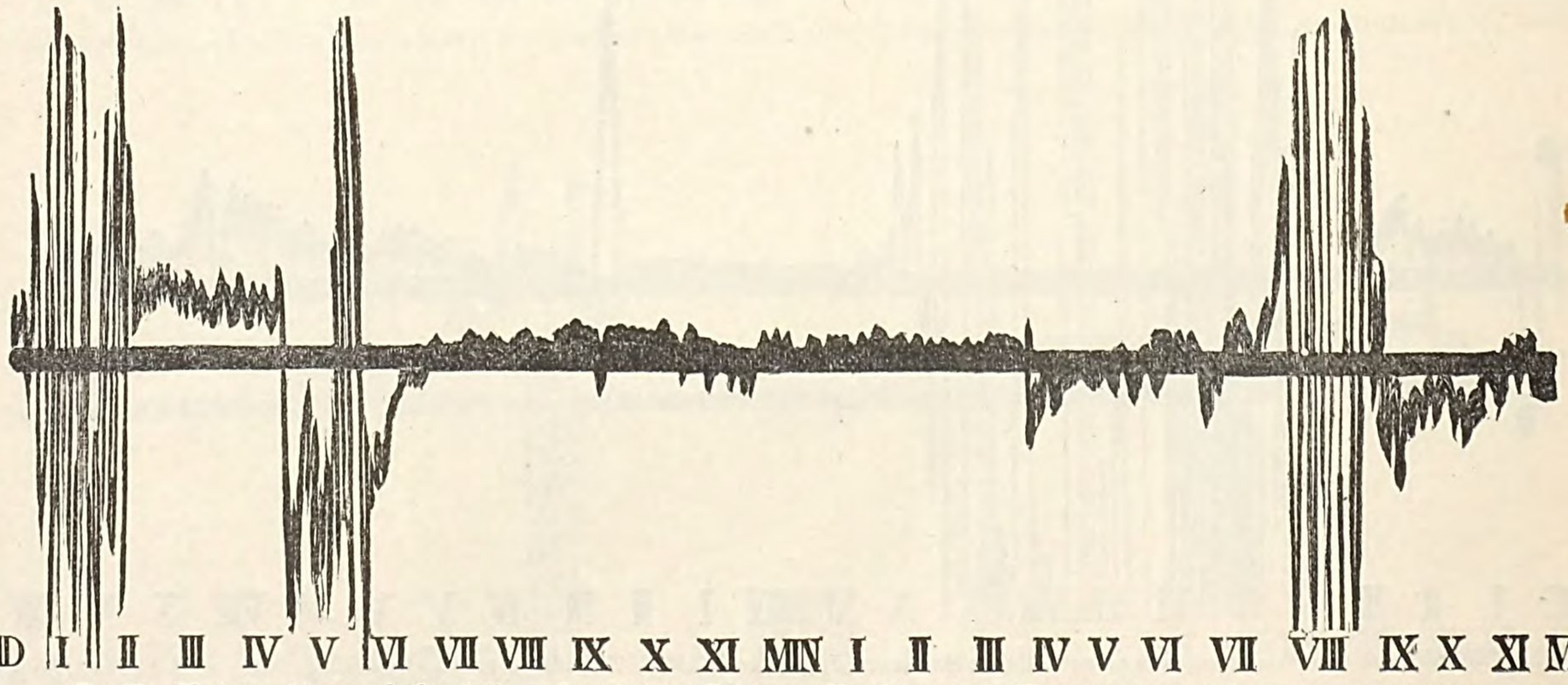


FIG. 72.—Photographic record of variations of potential at Baltimore, May 7 to 8, 1887. Thunderstorms with continuous rainstorm.

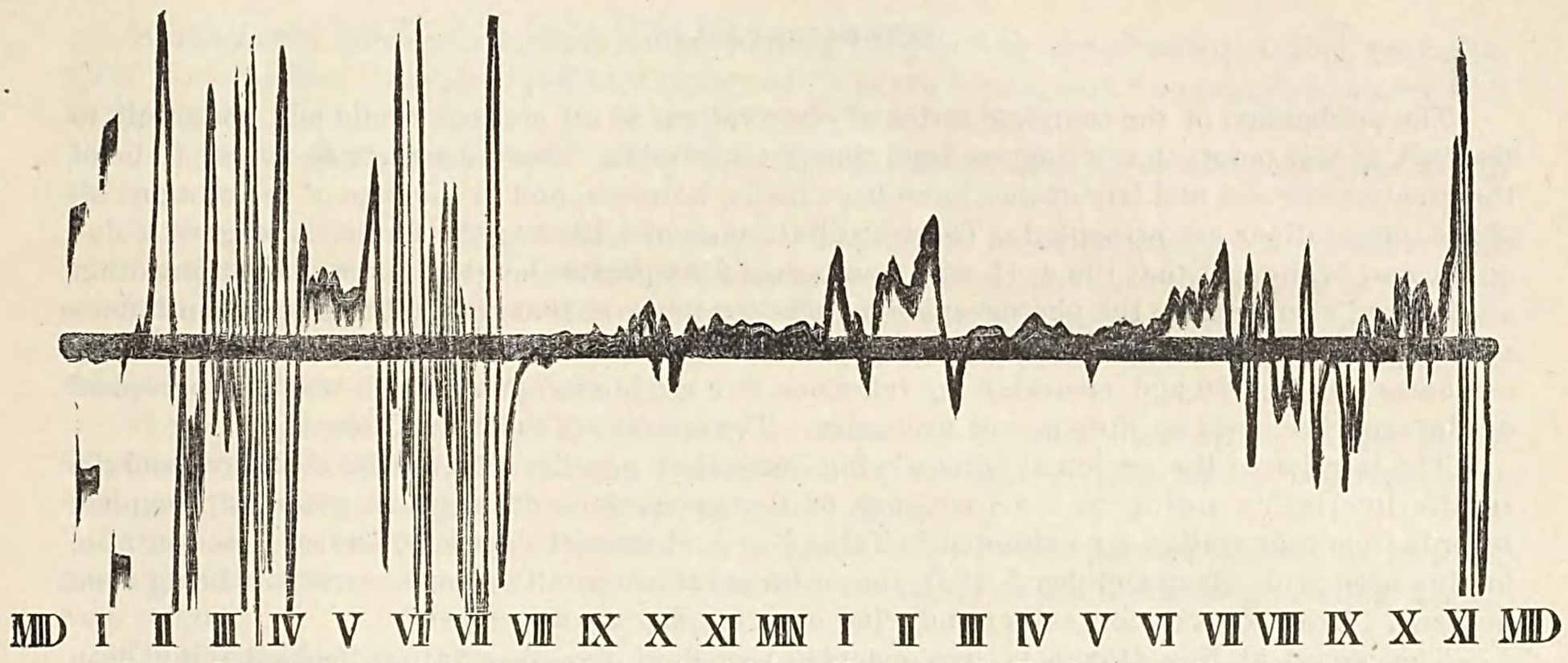


FIG. 73.—Photographic record of variations of potential at Baltimore, May 8 to 9, 1887. Thunderstorms with continuous rainstorm.

POTENTIAL DURING GALES OF WIND.

During the year 1887 a number of special observations were made of the potential indicated before, during, and after high winds.

The following notes were made by Mr. A. L. McRae, observer at Terre Haute, Ind.:

April 4, 1887.—Wind brisk in a. m. Threatening with westerly gale in p. m. Positive in a. m.; steady negative in p. m.

April 15, 1887.—Fair to cloudy weather. Wind brisk to gale winds all day. Variable positive and negative, all day.

April 18, 1887.—Rain and sleet followed by snow in a. m. Fresh northerly winds in a. m. Gale northerly in p. m. from 12 to 3. Negative during rain and sleet and part of the snow. Positive during the gale.

April 22, 1887.—Northwesterly gale during a thunderstorm, 10 to 10:20 a. m. Variable positive and negative before, during, and after the gale.

April 23, 1887.—Brisk to gale westerly winds all day. Steady positive all day. Threatening and cloudy.

April 28, 1887.—Westerly gale from 10 a. m. to 5 p. m. Steady positive. Fair, with a trace of rain at 3 p. m.

April 29, 1887.—Gale to brisk northwesterly to westerly winds all day. Steady positive, except at 10:11 a. m. was negative for a few seconds. Clear weather.

May 2, 1887.—Westerly gale from 12:40 to 1 p. m. Variable negative and positive before, during, and after the gale. Thunderstorm and rain.

May 26, 1887.—Fair weather; westerly to northwesterly, brisk to gale from 12 m. to 6 p. m. Variable positive.

June 23, 1887.—Wind brisk to gale from 11 a. m. to 1 p. m. Variable negative and positive with threatening weather.

July 9, 1887.—Negative at 12 m., positive rest of the time. Wind brisk to gale from 12 m. to 5 p. m. Fair weather.

August 2, 1887.—Northeasterly gale to east brisk from 10 a. m. to 5 p. m. Variable negative and positive. Clear weather.

August 4, 1887.—Northerly gale from 3:40 to 4 p. m. Thunder and threatening just before rain. Steady positive during gale. Negative noted before and after. Westerly gale 4:57 to 5:10 p. m. High negative during rain and thunderstorm.

September 7, 1887.—Westerly to northwesterly brisk to gale from 12 m. to 7 p. m. Clear weather. Steady positive.

SUMMARY.

Weather.	Gales.	Negative.	No negative.
Clear (4)	4	2	2
Cloudy (3)	3	2	1
Threatening	3	2	1
Thunder and rain	3	2	1
Snow	1	0	1
Total	14	8	6

On one clear day and on one cloudy day the potential was negative for only a few minutes. On one thunderstorm day the potential was positive during the gale but negative before and after it. The potential was negative before the gale during snow.

GENERAL RESULTS.

The publication of the complete series of observations at all stations would add so largely to the bulk of this report that it has not been thought advisable. Such abstracts as appear to be of the greatest interest and importance have been made, however, and in the case of two stations all of the observations are presented. These are Baltimore and Ithaca; the former is of great value on account of the fact that the work was maintained for a greater length of time than at any other station and also because the photographic registration in use at that station furnishes a continuous record for both night and day. In the preparation of tables from the photographic sheets, hourly ordinates were drawn and measured by reference to a calibration mark which was photographed on the sensitive plate as often as was necessary. The results are shown in Table A.

The location of the station at Ithaca being somewhat peculiar owing to its elevation, and the results interesting owing to the frequency of the appearance of negative potential, complete records from that station are exhibited in Table B. A change of exposure, and of observer also, having been made about October 1, 1887, the series is broken into two parts, each part being summarized. Brief notes as to weather and wind on every day are appended.

The record at New Haven is less complete, some of the observation books having been unfortunately lost. A nearly complete series extending over 1 year, from August 1, 1886, to July 31, 1887, will be found in Table C.

As the most promising analysis of the results appeared to be that which would reveal the relation between electric potential and precipitation, the observations on clear and fair days have been separated from the others and are collected for the various stations in Tables C to K, inclusive. By clear and fair days are here meant those on which the sky was at no time more than three-fourths covered by clouds, no precipitation occurring and the electric potential being continually positive. Brief weather notes are appended and the days are generally arranged in groups of ten, sums and means being found for each.

The Baltimore observations, however, have been collected into groups of 30 days each. Where a considerable change in the conditions under which the work was done has occurred, such as a change in exposure, electrometer, observer, etc., the results are sometimes summarized accordingly. This is the case with the observations at Ithaca, Boston, and Columbus. At the latter station a Thomson portable electrometer, by White, of Glasgow, was in use in 1887 and up to the end in July, 1888. The arrangements for the use of the Mascart quadrant, which had been in use before, were quite unsatisfactory, as it was necessary to carry the wire joining the collector to the needle on the outside of the building in which they were located, for some distance, and it was difficult to maintain good insulation. Some other differences in the way in which the observations are grouped and summarized in the tables arise out of differences in the number made per day, etc., and will be self-explanatory.

In the next series of tables, L to T inclusive, is given the electric potential of the air on days on which precipitation occurred at the place of observation, attention being given only to the sign of the electrification.

With a single exception, the exhibit of numerical results is in each case preceded by extracts from the daily journal of the observer, giving brief notes of interest in regard to other meteorological conditions which existed at the time. The results are then tabulated as follows: In the first column the date is given; in the second the time of the beginning and ending of precipitation; then two columns headed respectively "before" and "during"—and each subdivided into three, and referring specifically to observations made *before* precipitation and *after* precipitation. The first subdivision of the former is headed "no observation."

When a mark is found in that column opposite any date the meaning is that *no observation* was made before the beginning of precipitation, that is to say, it began before the first observation of the day.

The next subdivision is headed "negative first observed" and in it will be found the time, in hours, of the first observation of negative electricity before the beginning of precipitation. If no negative was observed before precipitation began, a mark is made in the third subdivision.

Marks in the three subdivisions under "during" imply "no observations during precipitation," if in the first, "negative potential observed" if in the second, and "no negative observed" if in the third.

"Negative after precipitation" heads the next column and brief meteorological notes are in the last.

In the case of the Baltimore observations it was possible to know with great certainty just when negative electricity was observed previous to precipitation, and the time column is therefore subdivided into several parts so as to exhibit more definitely the time of its appearance.

Of the St. Louis observations only those of the year 1861 are available for this table, the others having been published by summary.

The arrangement of Table T, containing a résumé of 8 years' observation at the Royal Observatory of Greenwich, is necessarily unlike that of the others. The time of beginning and ending of precipitation is not given in the published reports.

Only the prevailing kind of electricity is given, and for this purpose the day is divided, generally into four or five periods, and one kind of electricity is put down as prevailing during each period.

Thus, if the potential was positive during an afternoon except for a brief period when negative was recorded, the prevailing electricity would be recorded as positive. In this way slight precipitation may have occurred with negative electricity and still the potential recorded as positive. In this table, if precipitation and negative potential were both observed on the same day, that day is noted in the first column under "negative and precipitation."

Thus, in some cases, there may have been no negative either immediately before, during, or after the precipitation as there is no means of determining accurately the time relation between the two. The table is valuable, however, as showing the relative number of appearances of the two phenomena on the same day.

Supplementary to this series of tables and of equal importance in determining whether any relation exists between the appearance of negative electricity and precipitation are the notes made at the various stations of the occurrence of negative potential *without* precipitation, arranged under U to Y inclusive.

It is here shown that in many instances while there was no precipitation at the place of observation, it occurred within a radius of 200 miles, and to its influence may often be attributed the negative potential observed.

At the same time it will also be noted that there are many appearances of negative potential which can not be thus accounted for, nor by the appearance of clouds or other phenomena with which it is often associated. As an illustration, at Boston, on April 25, 1888, the observer notes "negative reading without a visible cloud and no wind to raise dust. Generally clear throughout the eastern part of the country. No other negative values seen during the day."

A table summary of the Baltimore notes is given, in which the relation between the appearance of a negative potential without precipitation, and the direction of the prevailing wind is shown The days are also classified into "cloudy" and "clear" and the number in each column indicates the number of times negative electricity without precipitation was observed in each month, under conditions indicated at the head of the column. Perhaps the most notable feature of this summary is the absence of any record of the occurrence of the phenomena during southwest winds.

RÉSUMÉ AND CONCLUSIONS.

As already stated in the introduction, the primary and it may be said the sole object of this investigation was to determine whether observations on atmospheric electricity could be made useful in weather forecasting.

The results obtained have, therefore, been classified and studied with this object in view.

Early in the progress of the work, the extreme local character of the phenomena exhibited became evident. It was found that instruments similar in every respect, separated by a distance of a hundred metres might give very dissimilar indications.

It may be well to repeat here that when reference is made to agreement or disagreement of observations, the absolute potential indicated is not considered.

This depends so largely on the nature and locality, and especially the elevation of the exposure, that absolute values are as yet not comparable, although it is believed that some of the devices suggested in the consideration of "Instruments and Methods" are capable of making them so. As the matter appears at present, however, this does not seem to be of great importance, as it is in the variations of potential as compared with variations in other meteorological elements that any systematic relations between them must be sought for. Experiments already described seemed to prove that even when great difference exists in absolute values, these variations will be sensibly in agreement whenever the exposures are near enough together to insure subjection to the same electrical influences. That this influence often controls or is uniform over only a small area was soon demonstrated, as also that at times when the disturbance was more energetic the area involved, in which a fairly uniform series of changes could be observed, was greatly increased.

The comparison of simultaneous observations at 5-minute intervals, extending through several days at the various stations, failed to show any similarity of fluctuations or movement of electric disturbance from one part of the country to another, and the same conclusion must be drawn from the regular observations. It must be said, however, that the number of stations (at no time greater than six), distributed as they were over a wide extent of country, was too small to justify great confidence in this negative result. The well-known electric activity about the time of the occurrence of precipitation, whether as rain, snow, hail, or sleet, was made the subject of special examination, attention being particularly called to the appearance of negative potential in connection therewith. Observers were instructed to study the appearance of negative electricity before and during precipitation, and at one time the hope was indulged in by the writer as well as by several of the observers that this phenomenon might afford great assistance in the prediction of local storms, rains, snows, etc., which offer so much difficulty in forecasting by present methods.

Further observation and investigation, however, did not justify this expectation, serving rather to increase the range of meteorological conditions under which negative potential might be looked for, and to diminish the definiteness of relationship between it and precipitation. That negative electricity is tolerably certain to be observed in connection with precipitation in a majority of cases is doubtless true, but it does not appear in such a way as to be of any value in forecasting.

A general summary of the results bearing on this question, as shown in the tables on previous pages, will be useful in this connection.

It is as follows, the numbers in each case showing (1) the total number of cases of precipitation in which observations were made *before precipitation began;* (2) the number of these in which negative potential was observed before precipitation began, and (3) the number in which no negative was observed before the beginning. It should also be stated that "before precipitation" is intended to cover a period of several hours, so that all cases are included in which there is any reasonable probability of the two phenomena being related to each other.

Negative potential preceding precipitation.

Station.	Total cases.	Negative preceding.	No negative preceding.
Terre Haute	90	59	31
Columbus	72	43	29
Ithaca	97	68	29
Baltimore	346	190	156
Washington	49	20	29
Boston	38	12	26
St. Louis	67	9	58
New Haven	34	5	29
Total	793	406	387

It thus appears that negative electricity preceded precipitation, the time varying from a few minutes to more than 10 hours, in a little more than half of nearly 800 cases, the percentage of its appearance being 53, while that of its non-appearance was 47. But notice should be taken of the negative character of some of this evidence, in that because many of the observations are eye observations, generally made at stated periods, it is impossible to say with certainty that negative potential did not occur at some time without being noted by the observer.

That such was not the case in any great degree is shown by an examination of the Baltimore observations, which constitute almost half of the above totals, and in which it was possible always to know whether negative potential had occurred. In this case the percentage of its appearance was 55 and of its non-appearance 45, being but little different from the results obtained from all stations.

Owing to the nature of the Kew tables already referred to, it is impossible to analyze the results so as to bear directly on the question. It is interesting, however, to note the following summary of these observations, it being remembered that reference is had only to the occurrence of negative potential and precipitation on the same day:

AT KEW.

Negative with precipitation	1,141
Precipitation without negative	722
Negative without precipitation	167

From which it will be seen that the two phenomena occurred on the same day in 1,141 cases, and *separately* in 889 cases.

But if it could be shown that negative potential invariably preceded precipitation, it would be still more important to inquire whether precipitation always followed the appearance of negative potential. An examination of the notes which bear on this question, presented in previous pages, shows that 311 cases have been noted in which negative potential was indicated unaccompanied by precipitation. In a considerable number of these, perhaps one-half, it was observed that precipitation was either actually taking place within what might be called a reasonable distance from the station, or that it did follow at some neighboring point within a few hours.

In many cases, however, nothing of the kind took place. At Baltimore, where 126 cases of "negative without precipitation" were observed, 26 only were followed by precipitation at that station on the following day.

Indeed, it appears to be abundantly proved that negative electricity may be and was frequently observed, apparently without being in any way related to precipitation, past, present, or future, and that it may be due to other causes, many of which are extremely local in their character.

Taking the facts above related into consideration, it seems safe to conclude that observations on atmospheric electricity do not promise to be of great service in forecasting the weather. The subject is one of great complexity, and, undoubtedly, owing to the local character of the phenomena, a rather close distribution of a large number of observers over a comparatively small area would tend to remove some doubts as to its utility which may exist.

Unfortunately the work requires observers of more than usual skill and intelligence and the equipment of a station is somewhat expensive. A number of intelligent and willing volunteers might undertake such an investigation, and the appliances now in the possession of the Chief Signal Officer might be wisely employed in the further study of the subject, and that without additional expense, by placing equipments at several of the more important stations of the service, where the employment of two or three observers would allow of the observations being carried on without special assignment.

It would be particularly desirable that some of the later forms of collectors be thoroughly tested and that a study be made of some other phases of the subject, such as the measurement of the "potential gradient" and its relation to weather phenomena, concerning which interesting conclusions have been reached through the recent researches of Prof. Franz Exner.*

The conditions under which the present investigation was made and the restrictions to which it was necessarily subjected, forbade an invasion of much territory of great scientific interest.

---

* Repertorium der Physik, 1888 March 31, 1889.

TABLE A.—*Hourly records, drawn from continuous photographic*

JANUARY, 1885.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1												
2	100	125	100	100	100	100	50	25	25	25	40	30
3	75	75	75	75	75	150	150	50	25	100	100	125
4	80	75	50	75	60	50	25	0	— 5	— 10	— 10	— 25
5	— 50	— 50	— 60	— 75	— 75	— 75	— 75	— 50	— 30	— 30	— 10	— 10
6	75	10	— 75	250	150	150	200	100	— 50	50	25	25
7	40	40	40	40	40	0	10	50	75	75	75	75
8	140	150	150	140	125	125	150	200	150	60	50	30
9	75	150	200	175	150	150	150	100	150	200	150	150
10	0	0	— 10	0	0	— 10	10	25	10	— 10	10	25
11	90	160	150	150	150	75	50	30	25	10	0	— 10
12	—120	—100	—150	—125	—150	—100	— 30	— 30	— 10	— 5	0	0
13	150	175	140	140	175	250	200	175	150	150	150	150
14	60	50	50	50	60	75	30	40	75	100	50	20
15	50	50	50	50	50	— 75	—100	—200	—225	—275	—250	—125
16												
17	— 10	— 20	— 40	— 60	— 50	— 30	— 5	5	10	10	5	5
18	50	50	30	25	20	10	10	10	20	20	20	20
19												
20	150	120	100	90	100	100	120	125	150	100	100	75
21												
22	10	40	40	50	50	60	60	60	40	30	10	10
23	10	20	20	20	20	10	10	5	5	5	0	5
24	—150	—120	—125	— 90	— 50	— 30	— 10	0	30	50	30	75
25	40	50	60	60	40	30	0	— 10	— 10	— 10	— 10	— 10
26	30	25	25	25	40	50	100	50	50	10	30	75
27	40	20	40	40	40	50	75	150	125	100	75	75
28	75	100	150	150	150	150	— 10	0	—150	—150	—100	— 75
29	0	0	0	0	0	0	0	10	0	10	20	10
30	125	175	150	150	125	160	250	75	60	50	40	40
31	100	100	110	100	100	100	100	150	175	150	160	150
Sums	1,235	1,470	1,270	1,605	1,495	1,525	1,520	1,140	870	815	760	825
Means	48	57	49	62	58	59	58	42	32	30	29	31

FEBRUARY, 1885.

1	10	10	10	— 5								
2	25	20	20	10	10	10	10	20	5	10	10	0
3	25	25	25	25	25	25	0	10	0	— 10	10	100
4	50	50	10	30	25	20	50	10	90	20	— 10	50
5	75	20	20	10	0	30	20	20	20	40	30	10
6	100	50	25	25	50	— 10	— 5	0	0	0	0	0
7	150	100	100	75	90	100	125	100	50	20	50	75
8	40	30	40	10	0	20	— 5	50	80	50	50	40
9												
10	50	0	0	20	30	0	100	200	0	200	20	20
11	— 10	— 10	— 10	— 10	— 10	— 10	— 10	— 10	— 10	— 10	0	25
12	0	0	0	0	0	0	0	— 5	— 5	— 5	— 10	— 10
13	30	— 5	20	25	25	40	100	75	50	30	10	0
14	10	10	10	10	20	10	20	50	60	20	50	60
15	60	50	50	50	60	90	110	125	125	125	100	100
16	— 30	— 50	—100	— 75	—200	—200	—300	—100	—200	50	0	— 10
17	40	30	25	10	0	0	0	0	0	0	0	0
18	0	50	0	10	0	0	25	25	30	25	50	40
19	50	60	50	40	50	50	75	100	100	80	0	0
20	25	0	0	0	— 5	— 5	0	0	0	0	0	0
21	150	150	80	50	30	20	20	10	0	0	0	0
22	100	100	100	100	110	110	90	75	60	40	30	30
23	100	110	100	90	60	30	25	10	10	— 10	125	100
24	100	100	125	125	125	200	175	100	75	40	25	25
25	250	0	— 50	0	—100	75	75	50	50	50	40	75
26	10	75	25	10	0	75	25	100	25	20	0	150
27	0	— 10	10	— 10	25	10	0	25	50	25	60	50
28	10	0	0	0	0	0	0	0	5	50	30	25
Sums	1,420	965	685	625	420	690	725	1,040	670	860	670	955
Means	55	39	27	25	18	30	33	45	28	36	28	40

registration, at Baltimore, Md., 1885, 1886, *and* 1887.

JANUARY, 1885.

1 p. m.	2 p. m.	3 p. m	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
10	50	250	100	75	75	100	100	100	100	100	100	W. br., r., sl., sn.
30	50	60	75	75	80	100	100	125	125	100	80	NW. br., clear.
100	150	150	125	100	100	125	125	125	100	100	90	SE. fr., fair.
— 25	— 25	— 25	— 25	— 25	— 25	— 25	— 25	— 25	— 25	— 25	— 25	Var. lt., sn., sl., r.
150	125	150	150	125	125	150	150	125	0	50	150	SW. lt., rain.
— 75	100	0	150	75	—100	60	60	50	50	50	40	SE. fr., rain.
75	75	75	75	90	100	100	90	75	100	125	125	W. br., fair.
75	100	100	100	90	150	150	100	125	75	50	50	SW. fr., fair.
150	100	100	100	100	50	50	50	40	0	— 10	0	SW. fr., clear, fog.
60	70	75	75	60	60	50	150	100	75	100	75	NW. br., clear.
10	20	100	75	80	30	80	50	10	—150	—150	— 75	SE. fr., rain.
— 10	75	100	110	125	110	125	150	150	175	175	200	Do.
65	80	65	65	65	75	80	75	100	65	75	50	NW. fr., fair.
125	160	100	125	100	75	75	60	50	50	80	60	E. fr., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	S. fr., sleet, rain.
10	100	30	20	125	150	125	100	110	100	50	25	E. lt., rain, fog.
5	0	5	— 5	5	0	10	10	10	10	30	30	NW. g., rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. fr., clear.
50	60	50	50	60	60	80	80	100	100	100	75	NW. fr., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. lt., cloudy.
— 25	— 10	— 10	— 50	— 5	0	10	0	25	20	20	25	SW. lt., clear.
5	5	40	30	30	25	50	25	5	5	5	5	NW. br., clear.
40	50	75	60	100	60	50	40	40	10	—100	—175	SW. fr., snow, sleet.
10	0	75	50	75	100	100	75	75	100	75	60	Var., lt., snow.
250	200	200	300	275	10	75	60	60	50	70	50	W. lt., cloudy.
75	50	50	80	75	50	60	50	75	60	50	30	NW. br., clear.
100	130	100	100	100	50	75	100	90	90	100	150	NW. br., fair.
— 50	350	350	250	100	75	60	75	50	25	10	0	N. lt., snow.
100	110	100	110	125	150	130	200	150	50	125	150	SW. fr., clear.
200	175	165	165	125	150	50	50	100	75	50	120	W. fr., fair.
140	130	150	150	100	50	50	75	75	75	60	0	NE. lt., fair.
1,650	2,480	2,680	2,610	2,425	1,835	2,145	2,175	2,115	1,510	1,465	1,465	
59	89	96	93	87	66	77	78	76	54	52	54	

FEBRUARY, 1885.

100	100	75	75	50	75	60	50	50	50	50	30	NW. fr., snow.
75	80	100	100	90	75	50	50	80	75	100	30	NW. br., clear.
100	150	100	75	60	20	25	50	20	20	60	50	NE. lt., cloudy.
10	0	100	100	50	— 50	—200	—150	100	100	50	100	S. lt., rain.
10	25	60	75	75	25	30	30	— 50	0	250	— 25	N. fr., rain, snow.
25	50	60	60	75	90	100	110	125	125	100	110	NW. fr., snow.
100	75	100	80	100	75	75	105	110	90	100	75	S. fr., cloudy.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NE. lt., fair.
— 25	— 50	— 20	0	0	—150	300	—200	—200	—200	300	—150	NE. fr., rain, t. s.
30	25	25	20	20	0	— 30	0	— 20	— 10	— 10	— 25	N. fr., rain, snow.
25	40	30	30	50	50	30	0	0	0	0	0	NW. br., clear.
50	60	60	50	60	50	50	75	50	25	25	40	NW. lt., fair.
— 50	200	— 10	125	80	25	20	20	20	50	50	20	E. lt., snow.
50	10	— 5	0	— 5	100	—100	150	— 10	100	125	100	NE. fr., snow.
90	110	125	130	125	100	10	50	10	10	10	— 20	SE. fr., clear.
60	50	50	40	30	25	5	10	10	30	40	40	E. br., rain, snow.
25	40	30	50	50	60	50	50	25	250	— 50	50	NW. fr., snow.
60	50	40	30	25	20	— 5	30	40	40	50	60	Do.
0	30	60	30	5	75	50	60	40	100	25	10	NW. fr., clear.
— 50	10	30	30	25	0	50	125	100	100	125	150	NW. br., clear.
250	200	225	200	130	100	100	100	100	50	125	125	NW. fr., clear.
150	125	100	75	75	50	60	50	50	60	75	75	Do.
100	100	110	110	125	90	75	80	90	75	100	100	Do.
175	200	150	150	175	125	75	75	200	—100	150	250	SW. fr., snow.
125	125	100	100	75	80	75	100	100	80	75	50	N. fr., snow.
150	175	125	100	60	50	— 50	20	10	100	100	50	NE. lt., snow, sleet.
50	30	60	50	20	20	30	30	25	25	30	25	NE. lt., snow.
75	60	75	80	100	150	125	100	80	100	100	100	SW. fr., clear.
1,760	2,070	1,955	1,965	1,725	1,330	1,060	1,170	1,155	1,345	2,155	1,420	
65	77	72	73	64	49	39	45	44	52	83	55	

TABLE A.—*Hourly records, drawn from continuous photographic*

MARCH, 1885.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	75	60	50	50	40	30	— 60	0	100	100	200	0
2	25	25	25	25	25	40	60	60	50	60	50	50
3	100	120	130	160	150	160	175	200	190	150	150	130
4	10	— 10	60	10	150	160	100	10	10	20	75	75
5	30	60	125	90	100	125	150	110	40	30	10	0
6	60	75	60	75	60	80	90	60	50	60	25	110
7	—100	—100	0	— 10	20	20	10	100	75	75	100	75
8	75	60	25	0	0	0	0	0	25	50	30	30
9	0	0	0	0	0	0	0	0	0	0	0	0
10	50	50	50	50	40	50	100	90	25	0	10	10
11	50	50	60	50	50	60	30	25	30	50	60	100
12	— 10	0	0	— 30	— 25	— 40	— 60	—100	— 50	—300	0	— 10
13	25	— 5	0	0	5	20	— 20	0	0	0	20	0
14	0	— 10	10	30	30	5	5	5	0	— 5	0	25
15	20	20	0	—300	— 25	— 20	— 20	0	0	— 10	— 25	— 10
16	0	0	0	5	10	50	75	40	50	30	50	30
17	25	25	30	40	40	40	40	0	0	0	0	0
18	20	20	15	25	20	30	20	25	30	30	50	100
19	— 10	0	20	10	10	10	0	0	—300	200	0	10
20	20	20	20	20	0	10	10	0	0	0	0	0
21	0	— 10	0	0	— 20	0	20	25	10	0	— 5	— 10
22	0	— 10	0	0	0	0	— 5	— 50	—150	30	10	10
23	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
25	— 5	— 5	0	0	0	0	0	0	0	0	0	0
26	50	0	0	20	10	— 5	0	0	0	0	0	0
27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
28	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	110	75	75	75	60	75	— 5	125	175	125	150	100
31	30	30	30	40	75	10	10	60	75	75	50	0
Sums	650	540	785	435	825	910	725	785	435	770	1,010	825
Means	26	22	33	18	34	38	32	37	21	37	48	39

APRIL, 1885.

1	— 5	25	30	30	30	50	25	10	— 10	10	0	125
2	150	40	10	15	25	30	30	90	0	80	70	100
3	15	25	20	30	50	40	70	80	80	50	50	100
4	— 50	— 50	— 30	— 50	— 50	— 50	— 30	— 15	— 20	— 25	— 20	— 20
5	60	50	70	200	70	100	110	90	70	70	50	50
6	20	20	25	30	45	70	70	70	60	50	30	30
7	15	70	70	85	100	50	80	70	70	100	100	50
8	— 15	5	10	10	0	5	5	60	60	50	20	0
9	60	65	80	80	100	75	60	60	60	60	60	60
10	40	50	60	50	50	50	50	50	100	85	100	75
11	40	50	70	60	40	60	45	50	30	10	10	10
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	15	30	40	40	50	65	50	30	30	30	40	50
15	10	10	— 10	25	30	50	40	0	0	0	25	75
16	25	0	— 5	0	0	0	0	0	0	0	0	0
17	5	25	30	40	25	40	45	80	50	85	95	60
18	35	35	55	50	40	50	15	50	85	70	50	50
19	50	60	60	65	60	70	60	60	60	75	90	90
20	135	140	115	100	50	60	190	140	150	100	200	120
21	35	50	50	35	30	50	85	0	50	60	130	60
22	0	30	30	15	15	20	30	0	0	100	75	50
23	5	— 25	0	50	15	0	— 50	0	60	100	70	70
24	25	30	30	30	30	50	20	0	0	0	0	0
25	0	10	20	10	25	0	0	0	0	0	30	30
26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
27	40	50	20	60	50	50	50	60	50	50	50	50
28	20	50	50	60	10	40	50	50	70	100	80	100
29	75	70	70	70	75	70	0	— 50	—100	—100	—100	75
30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sums	805	915	970	1,190	965	1,095	1,100	1,035	1,005	1,210	1,305	1,460
Means	31	35	37	48	39	46	46	45	44	53	54	64

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

MARCH, 1885.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
—100	— 50	— 50	0	300	—100	— 50	— 50	0	10	30	25	SW. fr., rain.
30	60	60	60	60	60	50	50	40	50	75	100	NW. fr., rain.
125	75	75	75	125	100	90	0	— 50	— 50	0	— 10	S. fr., fair.
75	80	60	25	5	0	0	0	5	5	125	50	NW. fr., fair.
30	25	10	25	0	25	10	10	10	30	50	25	N. fr., fair.
150	75	140	50	60	100	— 50	— 20	— 10	0	30	30	N. lt., fair.
50	60	60	40	75	— 50	10	0	20	30	30	20	Var. lt., snow.
50	60	50	40	30	30	30	30	25	20	10	5	NW. br., snow.
50	40	40	40	40	25	50	50	50	50	50	50	SW. br., fair.
20	30	30	30	30	25	0	30	30	25	60	60	NW. br., clear.
75	75	100	90	60	20	0	20	10	10	10	10	NW. fr., cloudy.
—100	— 50	— 60	— 20	— 90	— 75	—100	0	100	75	25	0	SW. lt., rain, snow.
30	30	10	25	0	20	0	40	50	60	100	100	NE. lt., snow.
30	30	30	30	25	0	100	75	60	75	5	25	Do.
0	— 20	— 10	— 60	0	0	0	0	20	0	5	0	S. fr., rain, fog.
25	25	25	— 5	10	0	0	5	0	0	5	20	S. lt., fair.
0	25	25	25	25	25	20	10	— 20	25	25	10	NW. fr., clear.
50	— 10	100	60	60	10	25	0	— 10	— 20	0	0	Do.
20	20	20	20	20	20	0	0	20	20	20	20	NW. br., snow.
0	0	0	0	0	0	0	0	0	— 50	— 10	0	NW. gen., fair.
— 25	0	10	— 20	20	0	— 5	20	15	0	-20	0	NW. fr., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. fr., snow.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. fr., fair.
— 25	— 10	0	0	0	0	0	10	5	10	0	— 5	N. fr., fair.
0	0	100	0	0	0	0	0	— 10	— 10	— 10	— 25	NW. fr., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. lt., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. lt., rain, snow.
100	100	100	100	75	90	100	150	250	150	100	100	N. fr., snow.
50	100	75	100	100	50	125	75	75	30	20	30	W. lt., fair.
25	10	20	0	— 5	20	—100	— 20	— 50	75	25	0	SE. fr., rain.
735	780	1,020	730	1,025	395	305	485	635	620	760	640	
31	32	41	29	41	16	12	19	25	24	29	25	

APRIL, 1885.

180	160	100	60	0	— 40	— 25	0	— 30	— 90	75	—100	Var. lt., fair.
50	100	100	100	80	75	50	40	25	25	25	25	E. fr., fair.
60	100	50	90	60	50	— 40	— 50	— 90	50	—150	—150	S. fr., rain.
40	30	50	60	50	60	50	50	50	50	50	60	S. lt., rain, sleet.
50	50	50	50	50	35	25	30	100	35	25	—200	NW. fr., rain.
0	40	40	50	70	50	50	60	50	70	50	50	NW. br., clear.
50	20	100	50	60	25	— 40	40	20	0	— 10	0	E. lt., rain.
20	— 50	—100	—200	100	— 20	0	20	20	20	40	50	W. lt., rain, t. s.
80	75	50	50	40	50	50	50	50	60	50	50	NW. fr., clear.
50	80	50	50	60	40	50	50	25	60	60	100	E. lt., cloudy.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. lt., rain, snow.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. br., fair.
.....	15	30	— 10	—150	.....	20	20	25	25	15	25	NW. br., rain.
50	50	65	50	50	40	40	50	25	.....	40	25	NW. br., fair.
50	30	0	0	0	— 50	—100	300	0	30	—100	100	Var. lt., rain.
0	0	25	0	0	25	10	50	40	50	25	0	Do.
90	110	130	100	85	60	50	30	75	60	60	0	E. lt., cloudy.
50	85	95	75	50	35	35	45	60	60	50	50	Var. lt., fair.
100	150	200	150	160	140	160	150	140	100	150	120	E. fr., clear.
200	170	150	160	200	50	25	50	15	40	50	50	SE. fr., clear.
100	100	0	— 25	— 20	— 10	— 10	65	25	25	25	5	SE. lt., clear.
75	100	100	60	50	20	0	0	— 5	50	0	5	Do.
50	70	50	70	40	25	25	30	10	10	30	30	SE. fr., clear.
.....	— 10	0	— 20	0	0	— 30	— 15	— 5	— 60	0	10	SE. fr., cloudy.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	E. fr., cloudy.
.....	30	30	30	5	0	5	15	20	0	40	35	SE. fr., rain.
50	50	60	70	70	80	70	50	50	50	5	50	NW. fr., clear.
0	50	— 40	—150	40	60	50	50	20	50	75	75	SE. lt., rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. gen., clear.
.....	.....	.....	.....	.....	0	50	75	100	80	—100	0	W. fr., cloudy.
1,395	1,605	1,385	920	1,120	800	570	1,255	815	850	580	565	
67	67	55	37	45	33	22	48	31	34	22	22	

TABLE A.—*Hourly records, drawn from continuous photographic*

MAY, 1885.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	—250	250	50	—275	0	— 50	50	—250	— 50	0	25	100
2	20	20	20	20	20	20	20	20	20	20	20	20
3	0	0	0	0	0	0	0	0	0	0	0	0
4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	0	0	0	0	0	0	0	0	0	0	0	0
6	50	50	150	100	0	—100	100	120	60	50	130	200
7	— 70	—150	0	5	25	—100	10	—100	—200	—150	—200	0
8	60	20	20	40	25	90	— 50	200	0	70	80	80
9	60	— 5	50	0	10	20	60	50	150	100	130	120
10	120	80	90	100	105	110	100	110	95	110	115	110
11	40	35	35	35	35	40	35	80	110	100	85	50
12	90	50	85	100	75	75	75	50	50	35	25	25
13	50	80	55	—100	—110	—150	—100	— 50	—100	—200	—250	—300
14	0	—125	50	— 5	50	50	0	0	0	0	0	0
15	50	60	50	50	25	40	50	50	50	5	5	5
16	0	5	25	30	30	100	— 25	— 20	10	0	0	0
17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18	100	25	10	0	0	0	0	0	140	35	90	50
19	— 15	15	— 20	50	0	.....	.....	.....	.....	.....	.....	.....
20	0	50	50	50	50	50	— 50	15	50	40	50	70
21	45	5	50	60	5	50	50	75	75	50	50	30
22	—100	— 50	0	20	—100	—200	—200	—300	—200	—200	—100	— 50
23	— 50	— 55	— 50	— 45	— 45	0	0	— 20	— 40	— 25	— 30	— 35
24	0	0	0	0	0	0	0	0	0	0	0	0
25	50	20	0	0	0	0	0	0	0	0	100	75
26	200	100	100	100	100	100	50	50	30	30	20	0
27	60	50	50	60	50	50	5	45	50	50	50	50
28	5	50	50	50	— 25	50	50	65	45	60	85	110
29	75	75	65	60	60	60	55	65	65	60	60	60
30	— 20	20	0	10	0	30	50	50	20	— 40	— 50	— 50
31	—100	—100	— 65	— 15	0	— 25	— 25	— 50	— 40	— 65	— 60	— 60
Sums	470	575	920	500	385	310	320	255	390	135	430	660
Means	18	22	37	20	17	14	15	12	17	6	19	29

JUNE, 1885.

1	— 50	— 40	— 30	— 20	0	10	20	110	100	100	0	— 30
2	60	75	60	60	75	50	50	75	100	.....	.....	.....
3	100	100	90	90	100	100	100	100	150	150	155	130
4	75	70	70	70	70	65	50	50	100	75	100	100
5	0	0	0	0	0	0	10	10	30	— 10	0	— 20
6	60	75	100	90	100	100	100	120	130	100	100	90
7	75	70	70	70	70	65	65	70	55	55	60	60
8	60	60	60	60	60	30	25	0	— 60	— 60	— 25	0
9	75	75	80	80	105	110	150	165	200	150	150	150
10	70	75	80	90	100	75	70	100	100	110	150	175
11	70	40	70	65	30	50	140	90	80	85	110	10
12	60	50	60	60	40	85	70	50	75	10	0	0
13	65	60	60	45	50	50	50	35	50	50	50	100
14	— 20	— 30	— 10	— 10	0	0	0	— 10	— 10	— 10	— 10	— 10
15	0	0	0	0	10	15	20	50	60	60	60	60
16	50	50	50	50	60	80	60	50	40	25	25	25
17	—100	30	30	50	80	50	80	100	110	110	105	100
18	70	75	70	70	70	65	90	50	60	70	.....	.....
19	70	50	50	50	60	25	50	65	50	50	50	50
20	65	60	60	50	60	50	0	100	100	110	130	100
21	50	50	50	50	35	40	40	40	35	25	15	0
22	120	125	125	120	115	115	130	125	125	135	140	130
23	50	60	60	70	70	95	90	100	100	100	100	80
24	40	40	10	10	10	15	0	0	— 10	— 10	— 50	— 50
25	10	5	20	50	50	30	10	0	— 10	5	— 15	— 35
26	— 60	— 60	— 60	— 75	— 55	— 55	— 90	—100	— 95	—105	— 90	—100
27	100	100	95	90	60	50	45	5	5	40	70	60
28	0	— 20	—200	—300	—300	—250	—100	—100	— 50	0	0	0
29	95	95	100	100	100	85	100	100	100	85	100	.....
30	80	80	80	85	90	105	100	90	90	15	50	100
Sums	1,340	1,420	1,300	1,220	1,315	1,305	1,525	1,640	1,810	1,520	1,530	1,275
Means	45	47	43	41	44	44	51	55	60	52	57	51

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

MAY, 1885.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
.....	.....	.....	.....	.....	.....	100	50	45	35	25	20	E. fr., rain.
100	50	135	120	.....	.....	100	100	100	80	50	5	NW. fr., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. fr., rain.
0	0	0	0	0	0	0	0	0	0	0	0	NW. br., fair.
100	100	120	200	50	100	90	10	0	50	100	100	N. lt., fair.
150	130	200	260	120	200	150	200	100	60	100	50	SE. fr., rain.
—250	— 10	100	— 50	100	100	100	100	50	50	10	40	E. fr., rain.
50	50	100	75	75	80	60	80	50	50	70	60	NE. lt., cloudy.
120	160	120	50	—100	— 10	60	60	50	60	65	65	SE. fr., cloudy.
15	100	100	100	100	85	70	50	50	40	40	40	NW. fr., fair.
50	75	75	80	60	55	5	5	70	100	100	100	Do.
150	170	300	100	150	100	15	70	50	50	100	50	NW. lt., fair.
.....	.....	—175	—125	— 90	— 60	— 50	80	50	50	50	0	NE. fr., rain.
70	50	25	25	0	—200	10	60	60	50	50	50	NW. fr., rain.
50	50	60	45	0	0	50	0	— 75	— 15	10	0	N. fr., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	E. fr., clear.
100	50	90	100	50	60	45	60	90	50	50	100	E. fr., rain.
100	200	210	200	150	50	40	20	10	0	0	10	Var. lt., fair.
50	150	100	50	70	50	50	50	50	30	25	20	SE. lt., fair.
100	70	110	100	170	0	0	50	50	20	20	30	SE. lt., rain.
25	100	50	50	50	15	0	— 10	0	10	— 15	— 50	SE. fr., rain.
40	20	50	40	25	— 20	— 45	— 50	— 50	— 50	— 50	— 50	Do.
.....	.....	150	75	75	45	45	20	0	0	0	0	E. lt., rain.
.....	— 50	0	30	0	35	5	20	50	60	20	15	SE. fr., rain.
100	150	160	160	100	130	120	100	100	70	50	—200	SE. fr., rain, t. s.
.....	50	40	0	50	150	70	100	50	45	40	50	Var. lt., rain.
0	—130	—125	100	75	160	170	110	50	100	60	50	NE. lt., rain.
100	150	125	100	65	50	70	105	85	100	70	70	Do.
.....	.....	—100	— 75	—150	0	20	25	0	0	0	— 20	Var. lt., rain.
.....	.....	75	20	75	50	—100	—100	—100	—100	—100	—100	Do.
—300	—300	—200	300	50	60	0	—300	— 60	— 50	— 30	— 30	SE. fr., rain, t. s.
920	1,385	1,895	2,130	1,320	1,285	1,250	1,065	925	945	910	475	
44	60	70	79	51	49	44	38	34	35	34	18	

JUNE, 1885.

.....	100	150	200	200	.....	.....	.....	.....	.....	50	50	NW. fr., clear.
.....	.....	70	70	70	100	50	50	20	25	25	100	Do.
.....	.....	200	200	250	250	70	100	100	60	60	60	Do.
.....	100	150	250	—100	— 10	0	10	0	0	0	0	SE. lt., rain, t. s.
0	50	—350	—100	50	10	0	10	30	50	50	60	N. gen., rain, hail, t. s.
50	75	50	50	100	80	100	90	100	100	95	75	SE. fr., clear
.....	100	100	80	60	50	30	30	10	50	60	60	SE. fr., rain, t. s.
.....	.....	65	65	50	50	50	100	100	90	75	65	Var. lt., rain.
.....	.....	100	90	100	110	150	160	150	125	150	100	NW. fr., clear.
.....	— 10	— 10	150	150	100	100	60	60	50	100	80	Var. lt., fair.
.....	100	100	100	60	50	60	100	100	80	85	60	S. lt., clear.
100	150	130	110	100	100	50	110	95	70	70	70	S. fr., clear.
0	— 10	— 10	— 20	— 30	— 10	5	5	0	0	— 10	— 15	S. br., fair.
.....	.....	40	30	30	40	50	60	50	0	0	0	NW. br. thtn'g, lightn'g.
0	— 20	— 20	— 50	— 30	—125	—300	—100	— 90	— 50	30	50	N. lt., rain, t. s.
25	20	40	100	110	150	0	—200	— 20	0	30	0	W. fr., rain, t. s.
10	75	50	100	100	100	70	70	95	55	70	65	N. fr., rain.
.....	.....	.....	.....	.....	50	100	110	90	80	55	105	SE. fr., clear.
50	50	80	100	100	100	70	80	100	100	90	75	Var. lt., clear.
60	100	75	60	60	25	50	50	60	55	50	50	W. lt., fair.
.....	.....	50	55	50	100	100	100	110	100	110	110	SW. br., fair.
0	15	15	25	25	15	20	15	20	30	40	45	W. fr., fair.
20	25	30	40	50	40	0	20	10	25	30	25	NW. fr., clear.
.....	— 40	30	30	10	20	40	25	70	40	10	10	Var. lt., fair.
— 5	50	0	5	— 35	— 30	— 50	— 50	— 90	— 90	— 85	— 90	Var. lt., rain.
0	100	100	100	110	150	135	145	140	115	95	95	S. lt., rain.
150	— 20	100	80	80	90	90	60	60	0	50	30	E. lt., rain.
.....	.....	100	0	70	90	60	50	55	60	90	85	NE.fr., hvy. rn.(4.47)t.s.
.....	50	70	75	60	75	75	85	80	70	60	70	NW. fr., fair.
25	25	50	25	20	20	20	20	15	20	70	65	NW. br., fair.
485	1,115	1,555	2,020	1,870	1,790	1,195	1,365	1,520	1,310	1,605	1,555	
35	51	54	70	64	62	41	47	52	45	54	52	

TABLE A.—*Hourly records, drawn from continuous photographic*

JULY, 1885.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	50	60	55	55	90	100	100	110	95	50	60	50
2	45	40	40	20	40	50	10	10	15	0	30	250
3	— 15	— 5	— 10	— 15	0	— 30	— 25	— 50	— 20	— 20	— 20	— 30
4	50	60	60	65	90	70	5	30	45	50	50	50
5	50	50	55	60	80	105	110	110	105	105	80	80
6	— 25	— 25	— 25	0	0	— 20	— 20	— 30	— 20	— 20	— 60	— 60
7	45	50	50	50	35	20	10	5	0	— 25	— 45	— 50
8	85	100	110	200	230	250	250	265	250	260	255	250
9	0	— 5	— 15	— 15	— 10	0	5	0	— 20	— 20	— 15	— 10
10	0	0	20	20	20	50	30	30	30	30	30	30
11	140	140	135	130	135	150	130	110	110	105	110	110
12	50	25	40	40	30	40	45	60	50	55	50	50
13	60	60	50	60	50	60	50	75	90	80	85	90
14	15	50	50	—200	40	40	50	50	50	45	60	50
15	25	45	25	40	70	100	0	50	50	25	40	50
16	55	60	65	65	90	90	100	70	60	40	40	30
17	50	60	60	60	65	80	45	110	50	60	60	50
18	15	15	20	25	50	50	50	40	25	25	25	25
19	20	20	20	20	20	30	30	30	30	30	30	30
20	40	25	25	25	40	45	25	25	25	25	25	30
21	5	10	10	15	15	15	10	10	5	5	50	60
22	40	40	40	40	50	30	30	30	50	40	50	.....
23	40	45	30	25	20	15	0	0	0	0	100	50
24	60	40	20	60	50	0	10	60	100	130	100	70
25	50	50	50	60	60	80	60	50	40	40	60	50
26	40	30	30	30	30	50	50	50	20	20	20	20
27	20	0	0	0	0	— 50	0	50	30	60	50	.....
28	15	20	25	25	75	75	80	70	60	50	100	70
29	50	65	60	50	0	75	75	50	50	50	60	100
30	20	20	30	40	40	20	25	20	10	5	20	30
31	40	60	65	50	30	30	20	70	100	100	90	20
Sums	1,135	1,205	1,190	1,100	1,535	1,620	1,405	1,555	1,485	1,400	1,590	1,545
Means	37	39	38	35	50	52	45	50	48	45	51	53

AUGUST, 1885.

1	20	20	10	50	50	20	20	50	60	60	60	.....
2	20	20	15	0	0	0	0	0	0	0	0	0
3	—300	300	50	50	50	60	100	—300	—300	— 10	10	— 10
4	60	70	65	50	75	70	70	50	50	50	50	.....
5	30	25	30	20	50	100	50	50	35	30	30	30
6	50	45	40	50	70	100	20	20	50	70	60	70
7	70	90	110	20	95	110	70	30	— 5	0	— 60	— 30
8	20	10	25	40	30	50	50	50	50	— 10	25	50
9	50	50	60	70	80	100	110	90	90	85	85	100
10	20	20	15	15	0	5	5	0	0	0	0	0
11	85	85	70	40	60	80	100	70	80	80	100	70
12	80	80	80	70	20	80	50	100	100	110	100	100
13	50	50	50	70	50	50	60	70	70	60	50	60
14	30	30	50	60	50	70	60	70	70	70	60	50
15	40	35	35	40	50	60	50	65	50	40	25	50
16	45	40	50	40	30	30	50	60	50	50	50	50
17	50	60	50	50	40	80	— 10	70	65	50	60	60
18	70	70	80	90	70	80	50	50	40	30	0	0
19	0	15	15	10	15	10	20	0	0	0	40	40
20	25	45	40	40	40	45	50	50	50	55	70	50
21	50	50	45	60	95	50	50	90	50	40	50	60
22	25	40	50	45	50	40	35	45	30	40	20	10
23	10	60	70	60	30	0	0	0	0	0	0	0
24	60	60	60	60	70	90	70	70	60	20	40	50
25	65	50	40	45	50	50	50	20	0	0	0	0
26	30	30	40	50	50	70	80	80	30	15	5	0
27	.....	.....	.....	30	40	50	60	55	.....	.....	.....	.....
28	80	70	45	40	55	60	80	50	75	90	100	100
29	50	55	70	70	50	100	100	70	90	70	110	100
30	20	40	50	40	20	50	100	90	60	30	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0
Sums	905	1,615	1,410	1,375	1,435	1,760	1,600	1,215	1,000	1,125	1,140	1,050
Means	31	56	49	47	49	63	57	45	40	45	50	50

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

JULY, 1885.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
40	35	40	40	25	35	20	25	30	40	40	40	NW. fr., fair.
—150	— 30	— 10	— 10	0	— 15	— 10	— 10	0	5	— 10	— 10	NW. fr., rain.
0	25	25	30	40	40	50	50	55	55	15	30	NW. fr., fair.
40	50	65	80	80	90	110	95	90	65	45	25	SW. fr., clear.
— 10	—300	—200	— 30	—100	—120	—120	— 90	— 50	— 50	— 20	— 20	SW. fr., rain, t. s.
20	20	100	100	100	120	100	80	80	50	50	60	SW. fr., rain.
0	— 60	60	80	90	150	160	160	150	110	110	110	Var. lt., rain.
.....	— 10	0	— 5	50	50	20	25	0	— 10	40	10	Var. lt., clear.
.....	10	50	50	60	60	80	100	80	60	0	0	SW. br., lightning.
10	0	0	20	20	15	20	40	50	60	150	145	NW. fr., rain.
100	40	25	40	60	0	0	50	15	40	40	40	Var. fr., fair.
50	50	50	60	60	50	50	60	70	50	50	55	NE. fr., clear.
50	80	90	75	100	60	50	60	50	40	25	10	SE. fr., rain.
50	50	40	25	0	0	25	40	25	45	30	35	S. fr., rain.
50	75	100	140	90	50	50	50	70	70	50	100	Var. lt., clear.
50	65	65	60	50	55	40	50	50	0	50	25	S. lt., clear.
45	25	50	80	80	50	30	70	30	50	100	25	S. lt., fair.
20	20	20	60	30	10	— 10	—100	0	0	20	20	N. fr., rain, t. s.
.....	30	30	35	35	10	50	25	20	20	20	20	Var. lt., fair.
50	40	25	30	40	15	50	50	20	0	0	0	Do.
60	60	80	80	—125	75	50	50	50	50	40	40	Var. lt., lightning.
50	60	60	100	70	50	100	60	100	50	50	50	S. lt., fair.
50	75	100	115	100	60	100	60	65	80	60	85	SE., lt., fair.
—100	100	100	150	50	0	0	0	0	20	20	40	S., lt., rain, lightning.
30	60	100	125	75	30	30	30	25	60	50	50	Do.
30	50	—200	—350	—300	0	—200	0	20	20	30	20	SE. fr., rain, t. s.
15	50	50	90	50	50	50	50	30	40	25	15	E. fr., rain.
70	50	50	90	100	50	75	60	130	100	70	70	Var. lt., rain.
—250	100	50	70	50	30	50	50	40	40	40	25	Do.
40	45	50	40	25	10	25	50	65	60	45	30	Var. lt., fair.
.....	60	—100	0	20	100	60	20	30	20	20	0	E. lt., rain, t. s.
410	925	1,175	1,470	1,025	1,180	1,105	1,260	1,390	1,240	1,255	1,145	
15	30	38	47	33	38	36	41	45	40	40	37	

AUGUST, 1885.

.....	50	50	50	40	30	30	0	—300	30	25	30	S. fr., rain, t. s.
45	40	40	0	0	0	— 30	— 10	— 5	350	50	300	SE. fr., rain, t. s.
125	100	30	50	75	—200	—200	5	30	65	60	40	Do.
20	50	50	50	70	70	95	70	100	50	40	40	SE. fr., rain.
50	45	45	45	55	50	50	45	55	20	50	25	NW. fr., clear.
65	50	55	55	20	15	10	15	70	100	65	100	N. fr., clear.
—200	—350	—350	—300	—100	—100	— 90	— 20	20	— 50	— 50	— 50	N. lt., rain.
.....	.....	15	0	75	60	100	50	50	50	50	50	Var. lt., rain.
100	100	110	135	160	125	150	130	130	170	60	35	NW. fr., fair.
100	130	150	130	60	140	60	60	50	35	110	105	SE. fr., fair.
60	100	125	125	135	155	120	100	70	70	60	85	Do.
60	—200	50	—200	100	100	60	60	60	40	50	50	SE. lt., rain, t. s.
40	60	70	—100	—300	—300	—200	0	5	15	20	30	S. lt., rain, t. s.
.....	50	60	50	50	60	65	70	75	60	60	25	NW. fr., rain.
25	20	50	35	25	— 10	35	40	55	50	40	50	N. fr., fair.
50	50	45	50	55	100	80	95	90	100	100	100	N. fr. clear.
50	100	120	100	95	50	65	60	100	50	60	55	SE. lt., cloudy.
30	30	30	45	50	40	0	0	0	0	0	0	SW. fr., fair.
20	30	35	40	50	45	50	25	25	25	20	20	W. fr., fair.
50	70	65	80	50	45	— 10	80	40	70	60	20	NW. lt., clear.
50	55	50	80	85	80	20	30	0	35	30	50	Var. lt., rain.
40	70	60	60	70	—100	—300	20	20	200	15	15	SW. lt., rain, t. s.
.....	.....	.....	40	50	50	0	0	50	50	60	70	SW. fr., rain, t. s.
45	40	45	— 5	60	70	70	60	50	70	40	40	SW. fr., fair.
40	35	— 50	—300	—300	—300	—100	20	15	25	25	15	SW. fr., rain, t. s.
.....	.....	50	45	40	50	45	50	50	70	50	.....	NW. fr., rain.
60	70	60	60	65	70	80	50	80	50	50	60	NW. fr., fair.
100	100	100	100	95	50	60	50	25	25	20	50	N. fr., clear.
85	110	100	70	100	— 5	50	35	50	25	30	20	SW. fr., rain.
40	40	80	100	100	60	80	50	0	0	0	0	SW. lt., rain, t. s.
.....	.....	.....	.....	50	50	50	20	15	50	60	50	Var. lt., rain.
1,150	1,045	1,340	690	1,180	550	495	1,260	1,075	1,900	1,310	1,470	
46	39	46	23	38	18	16	41	36	63	44	51	

TABLE A.—*Hourly records, drawn from continuous photographic*

SEPTEMBER, 1885.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	60	65	50	60	50	50	60	70	60	55	50	50
2	25	30	30	30	40	50	55	65	50	50	50	25
3	60	70	60	100	60	70	0	70	60	30	15	0
4	35	50	105	50	50	100	100	150	100	100	100	100
5	100	70	90	70	80	105	100	100	80	70	50	50
6	75	70	75	70	70	70	70	140	110	100	100	100
7	120	95	100	100	100	200	150	100	120	140	150	120
8	80	85	— 5	50	50	100	60	100	70	80	100	100
9	—150	50	50	35	35	15	0	0	0	0	5	10
10	140	130	100	70	80	100	105	110	80	90	90	.....
11	15	15	5	10	35	60	70	75	100	100	50	70
12	40	70	100	100	85	50	130	140	115	150	150	150
13	90	85	75	80	75	80	85	70	75	80	60	60
14	60	100	90	70	70	80	90	50	90	100	110	120
15	30	40	45	50	50	60	70	70	80	85	75	95
16	40	40	50	50	70	110	90	60	70	70	60	60
17	50	55	50	55	55	100	50	60	80	30	75	60
18	50	60	65	10	80	20	— 5	20	80	10	0	0
19	60	65	70	70	70	90	50	60	20	15	0	0
20	50	50	40	35	35	40	30	35	25	25	25	25
21	35	35	35	35	35	50	30	50	50	.....	.....	.....
22	30	30	5	15	20	10	60	50	40	30	10	20
23	5	10	25	30	35	50	50	60	70	60	50	50
24	50	50	45	70	50	75	85	50	40	35	20	15
25	30	25	30	45	20	45	10	0	50	100	60	100
26	55	70	75	40	50	60	20	35	— 20	70	80	100
27	55	70	60	60	60	50	50	60	45	30	40	50
28	40	50	50	50	50	20	25	20	30	50	80	80
29	25	40	60	55	60	60	60	80	50	60	100	100
30	20	70	50	70	60	70	60	60	60	50	40	35
Sums	1,375	1,745	1,680	1,565	1,680	2,040	1,810	2,010	1,880	1,865	1,795	1,700
Means	46	58	56	52	56	68	62	69	65	67	66	68

OCTOBER, 1885.

1	50	50	50	50	65	40	30	50	50	10	30	25
2	50	40	30	30	20	25	20	0	60	— 10	0	0
3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	5	10	25	30	40	50	40	40	30	50	65	50
5	90	100	100	110	105	125	150	50	115	130	125	125
6	60	50	30	0	— 50	— 10	—300	—250	—300	— 10	—300	0
7	65	50	50	55	55	75	100	110	90	75	80	75
8	60	60	50	50	50	0	—150	—150	—150	— 75	0	— 20
9	40	65	80	25	60	80	25	25	75	80	75	60
10	0	0	0	0	0	0	0	0	0	0	0	0
11	100	110	95	95	90	100	100	140	150	150	25	150
12	60	65	90	75	40	80	80	80	75	75	90	50
13	—100	—250	—350	—100	— 75	— 20	— 25	0	10	25	10	25
14	25	25	30	30	50	85	110	100	100	90	75	65
15	30	30	50	40	50	75	75	90	110	90	75	75
16	65	50	50	75	75	105	100	100	175	160	175	150
17	75	60	100	50	60	60	65	30	60	60	100	150
18	30	75	95	60	65	125	125	130	95	80	60	60
19	60	60	50	0	0	90	10	— 50	105	110	110	110
20	60	50	60	60	60	75	80	100	90	85	80	75
21	10	25	25	0	—100	—300	—350	—200	— 50	0	0	0
22	50	50	50	40	60	95	130	90	80	75	50	40
23	75	50	40	40	75	100	75	50	65	125	80	50
24	60	60	50	50	55	65	75	75	70	65	65	60
25	60	75	75	50	30	40	60	100	110	100	95	95
26	75	70	60	60	60	50	10	50	— 50	150	140	100
27	10	50	10	50	30	25	75	— 50	— 25	0	50	90
28	75	25	50	25	50	150	100	10	75	95	90	80
29	50	60	50	50	35	25	40	40	60	50	0	80
30	—200	— 15	30	40	40	50	60	50	70	30	60	60
31	25	25	25	25	40	50	50	40	50	45	40	50
Sums	1,115	1,170	1,150	1,165	1,135	1,510	960	850	1,395	1,910	1,545	1,930
Means	38	40	40	40	39	52	33	29	48	68	57	71

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

SEPTEMBER, 1885.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
40	50	45	50	45	50	50	40	45	40	30	20	NW. fr., clear.
50	25	40	45	15	50	30	60	25	50	40	70	NW. lt., clear.
45	100	80	50	60	60	50	70	40	60	70	60	S. lt., clear.
0	0	0	0	200	5	100	—300	—200	60	150	70	Var. lt., rain, t. s.
65	65	100	50	200	0	50	45	50	50	70	50	Var. lt., rain.
100	100	100	85	100	100	150	170	100	100	100	140	Do.
150	150	170	190	200	160	100	120	85	50	100	100	Var. lt., cloudy.
100	60	130	105	100	50	65	60	65	65	65	60	S. lt., rain.
— 60	100	110	115	105	130	150	60	60	60	70	80	W. fr., rain, lightning.
0	60	60	65	50	50	— 20	15	20	15	30	0	NW. fr., rain.
0	0	0	0	0	0	0	0	0	0	35	0	NE. lt., rain.
100	120	110	130	95	75	80	90	70	20	65	100	Var. lt., cloudy.
—	—	—	100	100	90	90	90	70	65	60	60	S. fr., fair.
100	110	50	5	100	100	20	40	10	10	10	20	Do.
70	75	70	55	60	70	90	70	50	40	40	30	W. lt., clear.
50	55	60	5	70	20	40	50	50	70	60	55	NW. fr., clear.
100	120	50	100	130	135	100	70	60	60	80	50	NW. lt., clear.
0	0	0	0	0	0	0	70	30	0	50	50	SW. fr., fair.
50	65	55	55	120	50	60	70	40	25	50	50	Var. lt., clear.
35	50	50	50	70	75	60	40	30	50	20	30	NE. lt., fair.
50	70	95	60	50	80	65	40	50	15	25	20	NE. lt., cloudy.
50	—150	30	60	90	60	70	60	40	—150	0	0	W. fr., rain.
15	50	65	50	65	60	60	75	50	55	50	45	NW. br., rain.
5	5	15	25	50	50	50	60	40	25	25	50	SW. fr., clear.
100	120	70	100	120	100	50	—10	10	10	20	60	Var. lt., clear.
110	110	120	100	110	90	50	70	20	25	40	40	Do.
100	90	130	90	100	100	10	50	50	50	70	50	Var. lt., fair.
70	70	100	100	70	40	10	40	40	50	45	40	Do.
70	50	50	50	100	130	100	70	70	25	30	40	Var. lt., clear.
———	50	40	35	20	———	50	50	60	20	25	40	Do.
1,565	1,770	1,995	1,925	2,595	1,980	1,780	1,435	1,130	1,015	1,525	1,480	
62	68	74	69	89	71	61	48	38	34	51	49	

OCTOBER, 1885.

50	90	60	60	65	110	50	25	15	40	55	50	E. fr., cloudy.
------	------	------	------	------	------	------	------	------	------	------	------	E. fr., rain t. s.
10	10	10	20	10	0	0	0	— 5	0	0	5	Var. lt., rain.
—	—	75	100	100	100	90	80	90	75	80	90	SW. lt., rain.
65	60	75	70	60	75	100	110	75	85	90	60	SW. lt., fair.
—300	— 10	0	25	60	80	75	150	75	75	90	60	Var. lt., rain.
70	75	75	80	80	75	75	60	40	60	60	50	Var. lt., fair.
— 50	10	80	110	100	75	80	90	40	50	60	50	Var. lt., rain.
0	0	0	0	0	0	0	0	0	0	0	0	N. lt., cloudy.
60	75	150	160	110	100	110	100	80	25	150	100	Var. lt., clear.
125	125	140	65	95	125	100	90	85	65	100	75	Var. lt., fair.
75	90	75	60	10	0	— 10	—100	—150	—200	— 25	— 75	NE. fr., rain.
25	30	110	125	120	75	60	60	50	50	60	40	E. br., rain.
65	60	65	60	60	60	0	— 50	30	30	40	40	SW. fr., rain.
50	60	75	60	75	60	60	75	60	60	60	80	NW. fr., cloudy.
150	150	160	200	200	120	100	75	50	0	50	25	SE. fr., fair.
150	150	150	150	150	50	— 25	30	110	30	60	50	Var. lt., fair.
—	100	90	80	75	75	60	60	65	60	60	60	Var. lt., fair, fog.
100	110	100	90	100	90	75	65	75	75	50	50	Var. lt., cloudy, fog.
75	75	60	65	60	60	50	50	50	50	40	25	SE. fr., cloudy.
20	25	25	60	50	60	50	50	55	50	50	50	S. fr., rain.
50	60	60	60	75	80	100	110	100	75	50	50	NW. fr., clear.
50	90	90	90	75	100	75	75	75	60	60	50	Var. lt., rain.
50	50	60	60	60	50	50	90	65	60	75	60	N. lt., fair.
90	75	50	90	95	80	75	30	0	50	65	50	Var. lt., clear.
110	150	150	125	100	75	60	50	65	60	60	50	N. lt., clear.
100	110	150	100	50	110	0	50	0	0	10	60	Var. lt., fair, fog.
75	65	65	75	60	50	40	50	25	50	60	50	Var. lt., cloudy, fog.
50	50	30	40	50	200	—200	0	—300	—200	—100	—200	NE. br., rain, lightning.
50	30	40	50	50	0	— 5	25	25	25	25	30	NW. br., rain.
40	30	40	60	40	50	65	65	75	50	50	25	SW. fr., clear.
1,355	1,995	2,310	2,390	2,235	2,185	1,360	1,565	1,020	910	1,485	1,110	
48	71	80	82	77	75	47	54	35	31	51	38	

TABLE A.—*Hourly records, drawn from continuous photographic*

NOVEMBER, 1885.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	50	60	60	30	25	40	75	75	80	100	100	75
2	—200	0	— 50	0	50	80	90	50	10	0	0	0
3	50	60	60	75	75	110	90	90	80	60	60	60
4	75	125	150	150	175	175	225	200	100	90	110	100
5	130	125	125	100	110	60	75	180	150	100	50	75
6	80	65	75	100	100	100	90	105	80	60	60	60
7	60	60	75	250	—100	50	60	60	50	40	25	35
8	— 10	— 20	0	0	5	5	10	10	— 50	— 25	0	.....
9	10	50	0	—100	— 50	0	100	100	100	90	80	80
10	60	60	60	60	65	65	75	80	80	75	60	50
11	85	105	110	100	100	175	200	180	125	225	250	150
12	130	125	150	110	125	110	150	100	125	125	125	125
13	60	75	75	80	95	100	50	75	60	25	100	10
14	100	150	100	150	125	150	100	100	150	100	160	100
15	50	50	50	50	60	75	80	90	80	75	75	60
16	0	0	0	0	0	0	0	0	0	0	0	0
17	90	90	90	90	60	60	150	50	100	100	60	60
18	50	— 10	10	25	50	75	70	90	100	120	100	50
19	40	50	50	10	10	25	50	75	90	80	0	—125
20	40	50	50	75	75	100	90	110	100	100	100	100
21	75	65	75	75	100	100	25	50	65	50	0	50
22	120	100	75	80	105	75	60	75	100	100	80	60
23	0	0	—300	—350	—200	— 10	0	— 50	0	0	50	50
24	—250	—125	— 50	0	0	0	300	0	300	50	— 50	0
25	75	75	65	65	90	90	100	100	100	100	100	100
26	65	75	75	60	65	50	60	80	75	75	80	80
27	40	50	60	60	65	80	75	100	90	50	75	80
28	50	65	65	75	75	75	75	0	— 25	100	125	110
29	50	60	50	50	50	60	75	60	75	80	50	50
30	40	35	40	40	50	60	60	50	60	60	75	75
Sums	1,215	1,670	1,395	1,510	1,555	2,135	2,660	2,285	2,450	2,205	2,100	1,720
Means	42	58	48	52	54	74	92	79	84	79	75	64

DECEMBER, 1885.

1	45	40	65	45	50	25	15	10	— 25	— 70	— 30	—200
2	60	70	70	50	20	35	15	50	65	105	100	100
3	60	50	60	60	60	60	80	20	5	30	55	50
4	50	65	65	65	65	70	70	100	85	60	100	100
5	100	100	90	65	10	0	200	50	50	50	50	20
6	60	60	65	70	60	65	50	25	20	15	15	15
7	0	0	0	0	0	0	0	0	0	0	0	0
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	25	50	20	20	30	40	80	60	65	65	60	— 50
10	130	100	10	10	5	0	0	20	10	10	40	55
11	40	40	40	40	35	40	45	50	45	50	45	25
12	100	100	100	100	95	100	110	80	90	80	25	20
13	85	25	20	15	15	10	10	10	10	10	— 20	— 50
14	50	170	100	200	100	100	140	150	100	20	0	—300
15	70	100	60	90	90	100	110	130	130	100	120	80
16	150	180	160	210	230	230	300	300	300	200	180	150
17	150	135	135	150	150	150	175	140	150	200	175	175
18	30	20	20	25	20	5	20	— 10	20	30	30	25
19	120	110	125	125	165	100	100	80	50	60	50	50
20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
22	40	50	55	50	100	70	100	150	110	150	100	100
23	100	120	110	100	100	130	100	110	120	100	110	100
24	40	50	50	55	40	30	55	60	60	55	50	50
25	40	60	55	50	45	55	60	70	80	70	70	80
26	20	20	25	40	40	60	100	50	0	— 70	— 60	— 60
27	15	10	10	15	30	10	0	0	0	0	0	50
28	0	0	0	0	0	0	0	0	0	0	0	0
29	50	50	40	40	40	45	0	0	0	0	0	0
30	100	70	85	85	80	90	50	— 60	— 50	100	110	100
31	50	65	50	0	—300	— 400	—300	—300	—100	— 80	— 50	0
Sums	1,780	1,910	1,685	1,775	1,375	1,220	1,685	1,345	1,390	1,340	1,325	685
Means	68	73	65	68	53	47	70	56	58	56	55	29

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

NOVEMBER, 1885.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
200	125	100	60	—200	25	300	0	—300	0	—300	—300	Var. lt., rain.
.....	60	75	60	60	75	50	50	60	50	50	50	NW. br., rain.
50	50	60	65	60	75	90	80	75	75	80	80	W. br., cloudy.
100	125	100	125	125	110	150	125	125	100	105	110	W. fr., cloudy.
60	50	50	75	110	125	100	75	60	75	60	0	SW. br., rain.
75	75	75	65	50	40	40	30	30	10	60	50	S. lt., rain.
35	10	— 20	— 5	— 5	0	5	5	5	5	5	5	Var. lt., rain.
0	0	0	25	25	50	100	40	50	60	—150	—100	S. lt., rain.
75	75	75	75	75	75	60	60	60	60	60	60	NW. fr., rain.
30	60	60	65	75	80	90	80	100	80	75	75	NW. fr., cloudy.
250	125	125	100	125	125	150	125	175	250	200	150	W. fr., fair.
125	130	125	110	120	100	90	80	105	75	75	75	SW. lt., fair.
30	25	—100	10	0	50	60	75	65	60	55	75	SW. lt., rain.
100	150	90	160	150	75	125	100	110	65	60	55	Var. lt., fair.
50	30	10	0	0	0	0	0	0	0	0	0	NW. br., fair.
60	60	65	75	65	90	90	100	95	100	80	60	NW. fr., clear.
60	30	50	50	75	100	100	95	100	100	95	90	N. lt. fair.
60	60	75	75	60	65	50	40	30	30	20	30	Var. lt., rain.
— 50	0	— 5	— 5	25	50	25	25	25	25	25	25	SW. lt., rain.
100	100	100	100	125	100	100	75	50	— 25	— 20	20	N. lt., clear.
100	80	75	75	30	75	100	125	110	75	80	75	Var. lt., rain.
0	—150	— 50	—150	— 25	0	—350	—300	—250	—200	—200	— 75	W. lt., rain.
25	30	50	75	25	60	0	—100	—150	—350	—150	—150	NE. fr., rain, snow.
50	75	30	50	60	75	75	60	60	50	65	65	NW. fr., rain, snow.
100	100	100	100	75	75	85	75	75	75	75	75	NW. br., snow.
80	80	75	50	75	80	80	75	75	60	50	40	NW. fr., cloudy.
50	30	65	50	75	90	90	90	75	60	75	50	NW. fr., rain.
110	150	110	100	50	60	50	50	50	50	50	50	NW. lt., rain.
.....	0	0	50	75	80	75	60	60	40	50	50	NE. lt., rain.
75	60	75	75	75	50	40	30	50	25	30	30	N. fr., cloudy.
2,000	1,795	1,640	1,760	1,635	2,055	2,020	1,425	1,175	1,080	760	820	
71	60	55	61	56	71	70	49	41	37	26	28	

DECEMBER, 1885.

—250	— 50	50	20	30	30	30	40	50	50	45	25	NE. fr., rain.
100	100	85	70	80	95	100	120	100	85	75	60	N. lt., clear.
50	55	25	40	60	50	50	50	55	50	50	50	SE-NW. fr., rain, sleet.
100	100	110	130	150	85	55	80	70	90	80	80	S. fr., cloudy.
20	30	35	20	50	50	25	40	20	— 30	30	50	S. lt., rain.
0	0	0	0	0	0	0	0	0	0	0	0	SW. br., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	SW. fr., clear.
50	60	75	100	60	100	100	80	75	90	5	40	S. lt., cloudy.
—400	—200	100	200	150	95	150	50	100	80	40	40	Var. lt., rain.
50	60	60	70	75	75	90	60	55	50	45	40	Var. lt., fair.
50	65	70	50	55	60	50	50	50	50	75	90	NW. br., fair.
25	90	150	120	180	90	100	130	130	100	120	100	NE. fr., clear.
—400	—400	—400	—250	80	110	200	230	240	150	—250	—350	SE. fr., rain.
—100	—300	—100	70	100	110	50	90	90	80	70	70	W. fr., rain.
130	110	160	170	100	150	150	145	160	150	150	145	NW. br., fair.
200	180	200	175	210	300	70	90	75	150	150	150	Var. gen., fair.
150	200	200	150	250	170	150	125	80	30	30	30	E. gen., fair.
100	110	130	140	150	200	150	135	115	110	50	100	Var. gen., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	W. lt., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. br., fair.
0	0	0	0	0	0	50	50	50	50	50	45	W. br. fair.
100	50	75	80	75	150	200	160	150	20	20	100	W. fr., fair.
100	130	50	25	— 10	— 20	25	0	10	50	25	50	SW. fr., rain.
50	50	75	70	50	50	50	30	50	70	40	50	NW. fr., fair.
70	80	95	50	50	100	80	50	30	40	25	10	NE. fr., fair.
—100	50	0	20	70	50	50	120	95	70	60	—100	Var. lt., fair.
40	0	0	0	0	0	0	0	0	0	0	0	NW. fr., fair.
.....	50	60	45	30	35	25	30	30	30	30	35	W. fr., fair.
75	80	75	80	90	100	100	100	25	80	55	60	N. lt., fair.
150	200	170	130	150	110	90	95	100	100	100	70	SE. lt., fair.
0	50	70	70	65	80	50	40	40	60	60	70	Var. lt., rain.
360	950	1,620	1,845	2,350	2,525	2,240	2,190	2,045	1,855	1,230	1,110	
15	38	65	74	94	101	86	84	79	71	47	43	

TABLE A.—*Hourly records, drawn from continuous photographic*

JANUARY, 1886.

Day of month.	1 a. m.	2 a. m.	3 a m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	50	65	60	70	60	80	200	180	140	150	120	100
2	100	40	60	70	70	100	50	50	140	120	100	110
3	70	70	50	40	10	30	30	50	80	80	110	50
4	25	— 75	0	50	— 50	10	—200	—150	—100	—150	—200	— 75
5	5	5	15	10	20	35	75	75	75	50	50	50
6	40	40	45	45	50	50	60	75	55	50	50	50
7	50	65	60	60	70	85	80	110	70	70	70	70
8	90	90	70	70	75	90	75	100	100	85	85	80
9	150	—150	—150	—150	100	— 50	0	30	50	10	10	10
10	— 5	0	0	0	0	0	0	0	0	0	— 50	— 50
11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
22	100	120	120	120	130	140	145	135	160	200	250	200
23	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
26	160	140	100	85	150	100	120	110	100	110	130	150
27	120	130	140	135	100	100	100	110	130	105	—250	0
28	110	140	100	90	70	30	95	120	150	160	150	150
29	150	75	100	120	90	40	0	0	0	0	0	0
30	50	—100	— 50	— 60	0	20	50	100	50	50	50	70
31	0	0	0	0	0	0	0	0	0	0	50	60
Sums	1265	655	720	755	945	860	880	1,095	1,200	1,090	725	1,025
Means	79	44	48	50	63	57	63	78	86	78	45	64

FEBRUARY, 1886.

1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	80	60	60	45	50	40	15	0	0	0	0	0
3	50	40	70	150	175	190	270	50	20	45	25	0
4	75	200	250	200	10	— 5	0	0	— 20	— 50	— 50	— 35
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	210	260	220	150	150	50	10	0	0	250	20	0
10	100	85	120	70	110	170	200	200	200	170	150	150
11	30	50	65	50	40	— 10	—400	—400	—300	—400	—400	—350
12	40	40	80	60	35	30	50	60	150	120	100	110
13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	0	0	0	0	0	0	0	0	0	0	0	0
15	65	80	110	130	140	135	50	160	200	150	170	160
16	45	60	60	50	65	100	120	150	100	70	70	.....
17	60	70	70	65	60	80	90	50	25	15	150	150
18	90	60	60	70	100	100	120	150	120	80	50	50
19	30	45	50	55	25	60	100	70	75	75	0	0
20	20	20	25	25	25	25	25	—100	— 70	— 40	— 20	— 10
21	45	50	50	50	50	50	90	75	90	60	110	100
22	0	100	100	50	60	60	75	80	70	70	70	70
23	80	80	80	100	120	130	140	120	135	100	50	30
24	50	80	70	70	65	100	200	120	105	110	150	200
25	50	65	65	60	50	—200	0	0	0	0	0	0
26	50	25	30	40	30	0	0	200	100	60	20	0
27	.....	.....	0	0	0	0	0	0	0	0	0	0
28	65	60	60	50	50	20	0	0	0	0	0	0
Sums	1,235	1,530	1,695	1,540	1,410	1,125	1,155	985	1,000	885	665	625
Means	62	76	85	77	70	56	64	58	59	52	42	45

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

JANUARY, 1886.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
90	90	100	100	120	100	160	140	100	40	100	100	W. lt., clear.
80	120	200	190	70	60	70	80	80	90	90	90	E. lt., clear.
.....	70	70	70	50	35	25	30	20	50	55	40	E. lt., cloudy.
—100	— 70	—100	—100	— 50	— 10	0	0	— 50	— 5	0	0	E. gale, rain.
25	65	70	50	70	50	50	75	50	35	35	30	W. fr., rain.
50	35	50	50	50	45	50	50	55	50	50	50	NW. br., snow.
70	85	80	80	85	70	80	80	80	85	80	75	NW. fr., clear.
50	100	100	100	80	30	— 5	200	—200	—175	0	0	NE. br., snow.
200	200	100	50	30	30	15	15	— 20	0	0	— 10	NW. br., snow.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	W. gale, snow
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. gale, fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. fr., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Do.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	W. fr., rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	W. fr., sleet.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. fr., sleet, rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., fair.
.....	175	210	220	200	160	150	150	130	100	80	100	N. lt., rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. fr., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NE. fr., snow.
100	110	80	75	100	85	100	50	50	50	50	100	N. fr., rain.
110	140	50	20	20	110	120	130	100	110	60	110	N. lt., cloudy.
50	50	60	— 10	50	60	70	85	0	20	— 60	75	N. fr., rain.
140	120	100	140	50	150	100	120	95	100	— 50	—100	Do.
100	110	120	120	115	125	130	140	90	90	105	100	NW. fr., rain.
200	20	60	50	60	65	60	50	0	0	0	0	NW. br., rain, snow.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. fr., snow.
1,165	1,420	1,350	1,205	1,100	1,165	1,175	1,395	580	640	595	760	
83	89	84	75	69	73	73	87	39	43	40	51	

FEBRUARY, 1886.

100	100	85	80	85	80	70	60	40	50	55	70	NW. fr., fair.
10	100	75	60	50	65	60	65	85	60	65	65	SW. fr., fair.
0	100	50	— 10	0	— 20	— 15	0	0	20	50	100	NE. fr., snow.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. br., snow.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Do.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., snow.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NE. lt., cloudy.
200	220	80	200	180	250	60	40	15	0	0	150	Var. lt., cloudy.
210	300	300	250	210	220	150	160	100	100	100	80	Var. lt., clear.
150	200	160	180	180	150	135	30	50	60	60	50	Var. lt., rain.
.....	.....	— 50	50	90	40	35	50	50	40	50	60	NE. fr., rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NE. lt., rain.
0	0	0	0	0	0	0	0	0	0	0	0	W. fr., rain.
.....	160	200	250	200	220	130	130	200	100	50	65	Var. lt., fair.
80	100	100	0	0	45	50	50	50	40	40	30	SW. gale, rain.
.....	80	80	85	85	60	50	80	60	65	65	90	NW. br., fair.
85	90	60	60	95	75	90	75	70	50	60	70	Var. lt., fair.
45	40	40	35	20	100	80	70	80	60	35	40	SW. fr., clear.
.....	.....	70	30	50	— 10	50	40	70	65	60	40	NW. br., fair.
—100	— 50	— 60	— 80	— 20	20	25	30	35	45	40	40	NW. gale, fair.
.....	100	110	70	85	120	100	100	150	200	130	130	SW. fr., fair.
70	70	80	70	60	85	160	120	150	100	60	85	NW. br., clear.
0	0	10	— 50	30	55	60	60	65	80	60	50	SW. lt., rain.
200	200	200	200	200	220	200	140	110	60	60	60	SE. lt., fair.
0	200	—200	—150	60	50	110	100	50	0	150	—100	NW. br., rain.
— 10	—150	—100	—100	— 80	— 50	— 30	— 20	— 10	— 10	— 10	.....	NW. gale, snow.
0	50	50	50	50	50	50	55	50	60	40	50	NW. br., clear.
.....	.....	100	100	60	60	75	80	85	90	60	60	Do.
950	1,910	1,540	1,380	1,690	1,885	1,695	1,515	1,555	1,335	1,280	1,285	
79	106	70	63	77	86	77	69	71	61	59	61	

TABLE A.—*Hourly records, drawn from continuous photographic*

MARCH, 1886.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	120	80	90	100	70	70	70	70	25	0	20	60
2	— 5	— 5	— 5	0	0	0	0	0	— 10	— 10	— 5	— 5
3	10	0	0	0	0	0	0	0	— 10	0	— 20	10
4	0	0	15	10	20	25	30	35	25	25	25	25
5	50	50	50	50	50	50	50	40	20	50	40	40
6	60	50	30	50	50	50	50	60	40	50	30	30
7	50	40	40	40	40	45	80	70	50	50	50	50
8	60	40	40	— 5	— 50	— 50	—100	200	50	110	90	50
9	10	10	10	20	20	30	40	50	50	50	60	60
10	50	50	60	50	40	40	0	0	0	0	0	0
11	70	80	75	70	70	70	80	85	80	80	80	20
12	30	30	30	30	30	30	30	30	—110	— 70	—150	—100
13	30	10	0	25	0	20	10	0	— 10	— 10	— 20	— 20
14	25	30	30	30	30	40	50	60	65	65	60	50
15	50	80	60	70	30	60	60	— 5	10	50	50	60
16	70	80	90	60	65	60	30	50	60	30	25	25
17	80	80	80	90	95	100	100	100	95	110	100	100
18	50	100	80	80	90	60	70	60	40	25	25	20
19	0	— 10	0	—150	— 20	—200	—100	— 5	— 20	— 10	— 15	— 5
20	— 50	20	60	45	50	50	60	70	0	— 20	— 20	— 25
21	60	50	0	25	50	50	0	60	75	90	90	80
22	50	60	60	50	50	55	70	70	50	20	0	0
23	50	50	75	60	50	50	50	60	50	50	50	50
24	50	50	50	50	45	70	80	95	70	50	30	25
25	95	50	50	90	70	50	40	— 10	0	— 10	— 20	0
26	0	0	0	0	0	0	— 10	— 10	— 20	—300	—300	—100
27	—300	— 20	20	— 50	—200	— 250	—250	—200	— 25	—100	—100	—250
28	— 10	0	10	10	20	10	10	40	40	25	20	25
29	60	60	45	40	50	40	20	50	50	25	40	0
30	— 10	— 20	20	30	100	75	— 20	—300	—300	20	100	100
31	60	20	0	— 10	— 10	— 10	— 10	— 10	— 20	— 20	— 20	— 20
Sums	865	1,115	1,165	960	905	690	590	815	420	425	315	355
Means	29	38	40	34	32	25	21	29	14	14	11	13

APRIL, 1886.

1	20	50	40	30	40	50	— 10	— 10	5	5	5	10
2	0	0	0	0	0	0	0	0	— 5	— 10	— 20	— 20
3	0	— 5	— 10	— 5	0	— 10	— 30	— 60	— 10	— 5	0	— 10
4	— 50	—100	— 50	— 25	— 25	— 25	0	0	0	0	0	0
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	—150	0	—300	—300	—100	— 60	—150	0	0	0	0	0
7	40	40	50	30	50	50	50	— 10	10	30	30	30
8	35	40	35	35	35	50	50	50	30	30	30	30
9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	100	130	100	90	75	80	100	70	60	70	25	25
11	10	10	20	30	30	25	10	10	10	.....	.....	.....
12	25	25	5	5	50	50	60	40	40	75	90	90
13	— 50	40	40	40	40	25	50	25	— 10	50	0	0
14	50	100	100	100	60	60	60	60	60	90	110	120
15	80	80	50	20	0	0	0	.....	.....	.....	.....	.....
16	80	100	100	100	100	100	125	150	140	100	150	150
17	40	40	40	50	50	60	60	60	50	50	100	75
18	0	0	0	0	0	0	0	0	0	0	0	0
19	100	75	50	50	60	100	60	70	60	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	25	40	40	40	30	15	40	60	80	80	180	180
22	40	50	20	10	20	30	40	30	30	15	10	25
23	40	5	30	15	25	10	— 20	0	— 10	— 15	— 10	0
24	0	0	0	0	0	5	0	— 10	— 10	— 5	— 5	5
25	— 60	— 10	— 10	— 20	— 15	— 15	0	0	0	0	— 10	— 5
26	25	25	25	30	30	40	50	60	—100	— 60	40	.....
27	10	60	0	10	20	— 5	10	20	30	— 10	— 20	50
28	0	0	0	0	0	0	0	0	0	0	0	0
29	50	60	50	50	50	30	25	0	0	80	80	100
30	40	50	50	60	70	80	85	90	95	110	100	70
Sums	500	905	475	445	690	745	665	705	555	680	885	935
Means	22	39	21	19	30	32	30	34	25	34	47	55

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

MARCH, 1886.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
60	40	60	50	60	— 5	10	100	—100	0	— 10	— 5	NW. br., clear.
— 5	— 5	— 60	— 60	—100	— 5	50	20	25	0	25	20	Do.
5	20	15	0	20	15	20	25	20	20	0	0	Do.
30	40	45	40	40	30	30	30	30	30	30	40	NW. gale, fair.
40	45	50	50	50	50	50	75	60	100	110	90	NW. fr., fair.
40	40	40	45	40	40	80	100	10	80	80	60	N. W., fr., clear.
.....	60	60	100	110	150	110	150	100	100	70	70	N. lt., fair.
40	0	20	100	70	110	100	80	100	80	70	100	SE. lt., snow.
50	70	70	65	80	90	80	90	90	50	100	90	NW. fr., cloudy.
100	60	70	50	50	50	70	60	50	50	60	70	N. fr., fair.
70	75	60	70	80	90	100	150	100	70	20	10	NW. fr., clear.
—300	—100	0	20	50	— 5	40	50	50	10	20	30	SW. br., rain.
30	50	35	50	50	50	40	40	40	30	30	30	NW. br., rain.
.....	40	60	50	100	70	80	80	60	70	70	60	SW. lt., clear.
45	50	50	50	150	10	60	60	100	90	60	60	Do.
0	— 50	0	20	60	50	60	60	50	55	60	70	SW. fr., clear.
100	100	100	110	120	80	100	75	75	60	0	— 10	NW. fr., clear.
.....	.....	95	100	75	70	50	50	30	—150	— 10	0	SW. fr., rain
10	50	50	— 5	10	0	— 10	— 10	— 20	— 5	— 20	— 20	Var. lt., rain.
.....	150	— 10	— 50	100	100	100	—150	—300	200	—200	50	NE. lt., rain.
50	70	70	50	50	25	25	100	—150	— 60	60	50	SW. br., rain.
5	— 10	20	50	25	60	60	70	50	70	60	50	NW. br., rain.
60	70	20	20	15	40	60	60	60	60	60	25	NW. br., cloudy.
50	50	55	65	65	60	60	80	95	150	150	100	NW. br., fair.
10	25	0	— 30	— 50	— 50	0	— 20	— 15	0	— 25	— 50	SW. fr., fair.
— 60	—100	—100	—100	— 25	— 25	— 25	— 20	150	—200	—300	—200	Var. lt., rain.
—150	—300	—350	200	—300	—350	—350	—350	—250	—100	— 40	— 25	Do.
.....	75	60	60	60	60	50	60	60	90	90	80	E. lt., rain.
.....	—100	—300	—100	— 50	0	— 50	20	75	50	0	25	Do.
50	70	100	—300	—150	—200	110	—200	—300	—350	—100	50	Do.
— 35	— 40	— 30	— 50	— 50	— 50	— 50	— 35	— 20	— 15	— 5	10	SE. high, rain
295	545	355	720	805	610	1, 110	900	325	635	515	930	
12	18	11	23	26	20	36	29	10	21	17	30	

APRIL, 1886.

0	10	20	10	0	10	30	60	0	0	0	0	SW. br., clear.
.....	.....	10	10	10	10	10	5	0	— 25	— 25	— 20	NW. br., fair.
— 25	0	— 50	— 10	— 10	— 60	— 50	— 20	— 20	0	0	0	N. lt., rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. lt., rain.
0	50	60	60	— 50	—150	— 50	— 50	—150	— 20	— 20	—200	E. lt , rain.
10	20	20	50	15	40	15	— 20	0	0	10	25	NW. fr., rain.
30	50	50	50	— 20	20	10	20	20	30	40	50	Var. lt., rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. fr., fair.
50	60	60	45	40	30	50	100	120	40	40	90	Var. lt., clear.
.....	140	120	130	105	70	50	50	50	50	5	10	S. lt., fair.
.....	25	40	40	50	40	40	40	10	10	10	15	E. br., rain.
90	120	130	180	160	40	0	0	0	— 5	0	—100	SE. lt., rain, fog.
80	80	150	100	75	105	100	100	80	80	60	25	SE. lt., rain, t. s.
120	150	200	200	150	200	200	80	100	75	60	80	E. lt., clear.
100	150	200	200	200	180	140	130	100	100	100	100	E. lt., fair, fog in a. m.
120	160	150	60	85	120	100	75	40	30	25	50	E. lt., rain.
50	100	100	120	100	100	50	75	50	25	30	0	Do.
.....	100	100	100	100	75	70	100	50	20	50	60	E. lt., clear.
100	110	130	150	150	100	70	50	30	10	5	0	N. lt , clear.
60	80	140	70	80	140	170	70	40	30	15	25	E. lt., fair, lightning.
100	100	120	150	130	80	100	100	20	— 10	— 40	40	Var. lt., cloudy.
20	20	100	100	175	100	40	60	20	5	0	20	Var. lt., clear.
0	— 10	0	— 10	10	5	— 10	10	20	0	0	— 5	SW. lt., clear.
5	— 10	— 10	— 20	20	—300	— 10	0	— 50	50	— 20	0	W. lt., rain, t. s.
.....	60	70	0	20	—100	10	25	25	20	10	10	W. lt., rain.
— 50	60	60	100	150	60	50	10	0	40	40	40	W. lt., cloudy.
— 10	50	75	100	150	100	— 5	— 5	0	0	0	0	E. lt., cloudy.
100	120	130	150	150	100	100	80	90	60	70	50	Var. lt., cloudy.
70	110	100	60	70	50	50	50	70	40	30	30	E. fr., fair.
75	110	100	120	120	100	60	110	100	100	70	50	E. fr., cloudy.
1, 095	2, 025	2, 375	2, 315	2, 235	1, 265	1, 390	1, 305	815	755	565	445	
52	75	85	83	80	45	50	47	29	27	20	16	

TABLE A.—*Hourly records, drawn from continuous photographic*

JULY, 1886.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	75	60	30	40	30	20	10	40	60	75	90	50
2	30	—100	0	— 60	—100	—200	—500	—200	—450	—500	—450	—300
3	80	90	90	90	90	90	90	90	75	60	50	50
4	30	25	35	40	20	0	20	50	50	40	20	75
5	50	50	65	80	80	50	65	25	40	60	75	90
6	150	100	110	110	100	100	75	75	90	65	75	75
7	60	60	75	65	75	100	100	25	25	30	30	50
8	25	30	25	20	20	20	— 20	— 10	— 10	0	0	0
9	0	30	10	10	20	— 5	0	10	50	25	50	75
10	50	30	20	30	60	— 25	75	25	25	30	40	50
11	30	30	30	30	30	50	50	10	0	25	30	40
12	20	30	10	20	50	30	40	50	60	50	75	75
13	50	10	50	75	25	50	10	75	0	350	—200	0
14	70	— 30	50	40	0	50	70	70	90	—200	60	—250
15	70	60	60	50	100	80	50	70	105	90	100	60
16	0	70	90	110	140	170	150	100	100	80	100	80
17	50	50	55	50	60	80	90	50	40	40	40	50
18	100	90	90	70	75	75	75	100	90	65	125	125
19	50	70	80	100	110	130	150	155	160	125	130	130
20	25	20	20	10	30	50	40	20	25	20	25	30
21	200	150	— 50	350	0	—350	—300	20	25	10	50	50
22	50	40	50	60	75	100	80	50	60	50	30	40
23	30	30	30	30	10	0	0	0	5	10	10	10
24	30	30	50	40	50	25	10	10	100	100	90	100
25	40	30	50	30	25	25	— 10	100	— 50	20	—200	300
26	50	25	25	25	25	0	10	10	0	0	0	0
27	5	15	70	15	50	60	60	100	80	60	70	60
28	60	50	50	50	80	80	60	60	70	70	120	120
29	60	75	60	50	60	90	90	75	100	75	80	80
30	.....	.....	.....	.....	.....	.....	50	50	40	40	50	50
31	—300	50	20	30	70	80	60	60	70	80	70	70
Sums	1,240	1,270	1,350	1,660	1,460	1,025	750	1,365	1,125	1,045	835	1,435
Means	41	42	45	55	49	34	24	44	38	35	28	48

AUGUST, 1886.

1	75	— 50	— 10	20	25	75	80	75	40	50	65	50
2	105	100	70	30	70	90	80	90	80	90	100	90
3	125	100	90	90	90	75	90	65	50	75	95	100
4	60	65	65	60	80	110	60	65	50	50	60	50
5	60	50	40	50	50	75	100	60	100	100	60	50
6	40	60	75	0	50	60	60	75	75	105	105	130
7	0	10	— 20	—200	—250	—140	—220	—100	— 40	— 20	— 10	—10
8	55	60	60	60	60	65	70	75	50	50	50	50
9	75	75	50	50	45	15	0	25	50	40	25	25
10	75	70	75	70	65	55	20	55	70	55	50	55
11	5	5	5	5	10	10	10	10	10	10	10	40
12	50	55	20	45	50	55	50	50	35	30	30	30
13	50	5	50	65	30	45	— 5	20	70	60	55	60
14	45	55	75	90	75	55	55	55	50	60	60	60
15	25	30	30	30	30	50	50	55	70	70	75	.....
16	35	60	65	60	40	65	20	40	45	40	30	.....
17	40	40	15	0	20	30	30	30	40	20	20	20
18	50	50	60	60	70	80	60	70	80	60	60	35
19	120	140	125	120	135	140	140	130	120	110	90	.....
20	30	30	20	10	10	10	10	10	0	0	0	65
21	70	70	55	60	65	45	45	50	55	45	40	55
22	25	20	30	25	20	25	40	60	50	35	50	50
23	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
28	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sums	1,215	1,100	1,145	800	840	1,090	845	1,065	1,150	1,135	1,120	1,005
Means	55	50	52	36	38	50	38	48	52	52	51	52

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

JULY, 1886.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
50	75	50	60	65	75	30	60	65	50	50	30	E. fr., cloudy.
—250	—175	—175	—225	—100	25	100	80	100	50	125	50	NW. fr., rain.
30	25	10	0	25	30	50	75	60	10	125	60	N. lt., fair.
40	40	50	50	40	65	35	50	60	50	50	75	Var. gen., fair.
75	60	40	60	75	75	65	60	75	25	20	75	SW. lt., clear.
65	50	65	110	150	130	65	75	100	65	65	60	E. lt., clear, fog in a. m.
50	50	50	50	30	20	50	100	65	40	40	25	SW. fr., clear.
10	10	0	5	— 5	— 5	— 40	10	0	20	10	0	N. lt., cloudy.
0	75	100	100	100	75	40	75	50	40	65	60	SE. lt., cloudy.
60	60	60	60	60	60	— 5	— 5	10	10	30	40	W. lt., rain.
.....	40	50	20	30	35	30	50	75	30	30	20	N. lt., clear.
50	60	40	75	50	60	30	50	110	40	50	50	E. lt., clear.
200	60	115	150	100	100	70	50	60	30	40	20	E. lt., rain.
0	60	150	—300	100	— 50	— 50	— 20	80	60	60	65	E. lt., rain, t. s.
60	70	90	70	70	40	100	—300	0	—300	300	60	S. lt., rain, t. s. and tor.
.....	50	60	60	50	60	50	50	60	50	60	70	Var. lt., rain.
50	75	110	100	200	150	110	90	110	90	80	60	Var. lt., clear.
120	130	130	130	125	150	70	140	155	—200	—100	0	S. lt., rain, t. s.
40	50	60	60	60	75	75	90	75	50	25	30	NW. lt., clear.
25	25	20	30	10	10	— 5	50	65	75	75	50	Do.
20	0	— 10	10	60	60	20	100	100	90	90	60	NE. lt., rain.
30	30	40	25	30	30	40	30	30	30	30	30	W. lt., clear.
20	30	20	50	25	0	0	25	30	60	40	50	N. lt., cloudy.
75	100	125	100	90	60	60	60	60	50	50	50	E. lt., clear.
— 50	50	50	30	30	50	20	0	10	10	25	25	Var. lt., rain.
30	50	—200	—300	—200	300	—300	—300	250	100	5	5	W. fr., rain, t. s.
50	60	80	110	80	70	60	70	60	60	20	60	Var. lt., rain.
100	60	100	90	100	100	100	75	80	60	60	60	E. lt., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., clear.
60	80	90	90	70	80	50	40	60	50	—200	100	SW. lt., cloudy, light'g.
30	40	60	70	10	10	50	75	10	90	0	50	W. fr., rain, t. s.
1,040	1,390	1,430	940	1,530	1,940	970	1,005	2,065	885	1,320	1,390	
37	46	48	31	51	65	32	34	69	30	44	46	

AUGUST, 1886.

.....	—200	0	30	70	300	— 70	80	105	50	130	120	SE. lt., rain, lightning.
90	100	125	150	130	140	150	125	160	140	125	125	NW. fr., rain.
60	75	65	75	75	75	75	65	60	60	65	60	NW. fr., clear.
50	60	65	75	60	60	80	75	60	50	10	0	Do.
50	60	65	60	75	60	40	30	100	50	60	50	SW. fr., cloudy.
80	130	120	75	80	50	50	50	40	20	15	0	SW. fr,, fair.
0	10	— 10	20	30	30	40	50	65	60	50	55	Var. lt.,rain.
.....	50	75	85	70	70	60	115	65	65	50	55	NW. lt., clear.
100	100	125	100	100	100	100	80	105	95	85	80	S. lt., clear.
90	120	100	70	75	35	50	50	.....	10	25	5	S. lt., cloudy.
40	50	55	50	50	60	60	55	40	35	35	40	W. fr., fair.
30	60	50	45	85	85	45	100	65	60	65	50	Do.
60	60	85	140	100	70	70	60	40	40	50	55	S. lt., fair.
50	40	40	45	40	25	20	15	35	30	40	25	W. lt., rain.
.....	40	55	75	55	55	60	90	70	80	70	20	Var. lt., clear.
0	— 5	— 10	— 20	— 30	— 30	— 50	— 50	— 30	40	40	40	NE. lt., cloudy.
20	30	50	—100	— 50	50	15	50	20	20	30	40	NE. fr., rain, t. s.
30	40	55	55	65	70	80	85	95	105	90	110	NE. fr., cloudy.
50	55	75	80	45	35	25	40	20	20	50	50	E. fr., clear.
100	100	100	110	110	90	80	80	70	65	55	90	Do.
45	65	60	60	25	40	65	70	70	70	45	40	E. fr., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. fr., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	E. fr., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	E. lt., rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	N. lt., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	E. lt., cloudy.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	SE. lt., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	S. lt., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	SE fr., rain, t. s.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., rain.
945	1,040	1,355	1,280	1,260	1,470	1,045	1,315	1,255	1,165	1,185	1,110	
52	50	65	61	60	70	50	63	63	55	56	53	

TABLE A.—*Hourly records, drawn from continuous photographic*

SEPTEMBER, 1886.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	—250
16	— 50	— 65	— 50	—300	—200	— 75	— 40	40	0	— 20	60	.....
17	90	105	105	115	110	190	130	105	130	160	100	.....
18	50	50	50	30	60	70	0	30	60	60	80	60
19	70	65	80	60	80	85	80	85	60	70	60	.....
20	50	40	40	40	40	50	60	60	60	60	60	60
21	110	100	70	60	100	100	100	95	90	90	75	75
22	0	0	0	0	5	10	10	20	40	95	150	90
23	100	75	85	50	50	40	25	30	50	20	0	10
24	20	20	20	0	0	10	10	15	20	100	70	70
25	30	40	50	50	50	55	80	90	90	105	100	100
26	20	60	50	50	55	65	60	70	35	70	45	.....
27	65	60	60	50	50	65	90	100	120	80	70	40
28	40	40	55	30	30	10	25	60	0	10	10	95
29	10	0	15	20	200	—200	60	60	40	25	20	65
30	55	35	20	20	5	5	0	0	0	0	0	40
Sums	570	625	650	275	635	480	690	860	795	925	900	515
Means	38	42	43	18	42	32	46	57	53	62	60	43

OCTOBER, 1886.

1	40	35	25	10	5	0	0	0	0	0	60	60
2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	45
8	25	25	25	25	30	40	40	50	20	20	30	40
9	25	50	40	50	55	50	105	10	0	0	0	100
10	40	40	40	40	15	35	35	30	40	45	50	60
11	60	60	75	65	60	75	80	95	70	25	25	110
12	50	50	55	60	85	60	30	70	120	200	200	60
13	50	50	50	60	50	45	40	15	5	5	5	150
14	5	5	5	0	0	0	10	5	10	20	10	10
15	0	0	10	20	20	20	60	65	75	80	80	60
16	75	75	75	75	75	60	0	10	30	50	20	10
17	50	40	40	50	50	55	60	90	60	65	60	.....
18	120	150	140	120	105	100	100	100	110	110	70	70
19	60	60	40	30	20	0	— 25	0	60	60	60	60
20	10	10	10	10	10	0	0	15	30	60	65	65
21	30	60	60	70	70	70	—200	50	60	60	60	50
22	70	100	100	60	80	100	140	130	100	60	60	70
23	100	110	90	110	150	100	120	110	90	60	50	60
24	40	50	60	40	50	40	35	40	50	50	60	.....
25	50	70	75	70	100	100	70	120	100	100	110	100
26	— 10	0	10	0	0	20	25	0	— 10	— 10	0	— 20
27	—400	—300	—200	—300	— 60	80	— 5	20	10	0	0	25
28	0	0	10	0	10	10	10	40	50	70	65	75
29	90	100	75	70	100	60	80	105	80	70	60	70
30	55	50	—400	—200	— 20	40	60	65	60	50	60	45
31	50	40	20	30	50	60	90	80	80	60	75	70
Sums	685	930	530	565	1,110	1,220	960	1,315	1,310	1,310	1,335	1,445
Means	27	37	21	23	44	49	38	53	52	52	53	60

***registration**, at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

SEPTEMBER, 1886.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	N. fr., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NE. fr., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	E. fr., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NE. fr., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., cloudy.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Do.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Do.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	E. lt., cloudy.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., rain.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., cloudy.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. fr., cloudy.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	W. fr., rain, t. s.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	W. fr., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	SW. lt., fair.
70	45	55	40	35	35	25	20	0	— 20	— 30	— 50	E. lt., rain.
.....	160	125	100	130	80	85	85	90	85	80	75	Var. lt., rain.
150	200	200	200	230	140	160	170	120	70	70	60	S. fr., fair, lightning.
90	200	220	130	80	40	60	60	35	60	80	70	Var. lt., cloudy.
40	100	90	210	0	60	80	250	100	100	40	40	S. fr., rain, t. s.
60	65	65	70	75	100	80	70	70	80	75	110	W. fr., fair.
85	95	105	100	100	105	130	90	70	45	35	0	Var. lt., rain.
130	120	175	110	110	60	70	110	150	150	100	70	E. fr., rain.
10	0	0	10	30	55	15	30	25	20	20	10	Var. lt., cloudy.
100	100	150	100	100	80	100	50	50	20	10	40	SE. gen., clear.
120	170	180	85	50	30	30	40	60	70	60	60	S. lt., clear.
.....	— 20	10	40	50	50	55	40	50	50	60	60	SW. gale, cloudy.
35	30	85	105	70	10	70	75	55	60	60	40	SW. lt., fair.
85	75	150	100	100	80	65	100	120	105	80	10	S. fr., fair.
70	75	70	60	60	70	85	80	65	40	50	55	NE. fr., rain.
35	50	50	20	50	25	85	65	50	50	50	40	E. fr., fair.
1,080	1,465	1,730	1,480	1,270	1,020	1,195	1,335	1,110	985	840	690	
77	91	108	92	79	64	75	83	70	62	52	43	

OCTOBER, 1886.

.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	N. W. br., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. fr., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	S. lt., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Var. lt., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	N. fr., clear.
50	50	50	35	55	55	90	40	65	60	60	0	Do.
60	90	110	160	100	50	65	10	— 30	0	10	20	Var. lt., clear.
100	100	150	160	150	60	35	75	60	60	55	55	Do.
.....	110	160	160	150	90	90	90	60	80	100	90	Var. gen., clear.
100	150	155	200	140	150	90	70	70	60	40	40	Var. lt., clear.
40	60	55	50	80	75	90	70	60	55	50	50	Var. lt., fog, clear.
210	215	200	230	180	130	80	60	50	45	20	5	SE. lt., cloudy.
20	15	40	40	5	0	0	0	10	0	0	0	SE. br., rain.
65	65	70	70	100	95	100	100	100	70	80	80	SW. br., clear.
10	15	10	40	35	35	60	65	70	75	60	70	NW. fr., fair.
.....	120	130	140	120	95	130	240	100	90	140	120	NE. fr., fair.
65	90	105	250	200	160	80	80	65	70	70	70	Var. lt., clear.
100	100	75	100	100	70	40	25	15	10	10	0	E. lt., cloudy.
100	120	120	90	80	50	50	50	40	30	40	40	Var. lt., fair.
50	50	55	60	70	60	70	55	50	50	50	50	W. fr., rain.
65	60	55	55	70	110	130	60	25	50	60	50	W. fr., clear.
100	200	180	200	200	100	50	35	50	40	60	50	Var. lt., clear.
.....	70	90	100	90	90	70	60	60	60	70	100	E. fr., clear.
140	150	250	300	100	50	50	40	30	10	0	0	Var. lt., fair.
60	75	0	60	—200	100	0	—100	250	—400	—300	—350	NE. lt., rain.
0	15	10	60	10	80	80	50	— 5	50	— 50	60	Do.
25	30	50	50	60	80	70	70	90	100	90	100	N. lt., rain.
90	40	20	25	25	25	90	80	60	60	65	60	Var. lt., rain.
40	60	35	0	60	55	50	45	50	40	— 60	—100	NW. fr., rain.
.....	.....	65	75	55	50	50	75	80	50	70	80	NW. br., rain.
1,490	2,050	2,240	2,710	2,035	1,915	1,710	1,445	1,475	815	790	740	
71	86	90	108	81	73	68	58	59	33	32	30	

TABLE A.—*Hourly records, drawn from continuous photographic*

NOVEMBER, 1886.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	60	65	70	70	80	90	95	105	105	100	130	140
2	100	110	90	95	100	90	120	120	120	150	110	100
3	140	140	140	140	150	140	125	190	240	250	240	200
4	60	60	70	70	70	100	100	100	100	100	100	100
5	95	90	85	80	80	100	100	120	200	200	140	100
6	20	30	70	60	60	40	25	10	70	75	110	100
7	20	30	50	55	40	50	50	50	50	55	70	50
8	60	75	70	100	190	160	90	100	70	60	50	50
9	75	100	120	100	90	120	100	100	150	140	150	100
10	100	80	150	100	90	120	120	140	150	160	190	150
11	120	150	145	140	90	70	110	120	100	90	90	100
12	20	15	40	25	15	40	10	0	5	—100	0	— 60
13	10	10	5	0	0	40	40	50	50	45	45	40
14	25	30	30	30	40	40	50	60	60	60	60	60
15	50	40	40	50	50	50	70	90	85	60	50	80
16	30	50	50	20	40	50	50	100	65	70	100	90
17	40	50	0	0	40	50	10	10	50	100	50	50
18	30	40	0	10	30	20	—100	150	10	30	60	60
19	100	90	100	60	70	60	160	130	60	60	60	60
20	110	100	90	100	115	140	100	30	180	150	130	100
21	120	130	125	100	60	80	85	105	130	100	100	90
22	100	100	60	70	70	50	60	65	120	120	160	150
23	—100	—100	—100	0	10	0	50	60	80	80	80	60
24	70	60	— 25	0	40	40	50	60	60	50	60	75
25	50	60	65	45	50	50	60	30	30	50	60	50
26	50	50	50	40	70	70	80	90	60	90	85	85
27	100	100	90	100	110	130	160	170	190	150	100	100
28	140	100	120	120	100	80	75	80	140	130	125	130
29	90	120	120	120	105	110	115	150	155	150	100	140
30	110	150	50	—100	60	90	90	105	100	100	140	120
Sums	1,995	2,265	2,020	1,800	2,115	2,270	2,250	2,690	2,985	2,875	3,005	2,670
Means	67	76	67	60	70	76	75	90	100	96	100	89

DECEMBER, 1886.

1	110	90	85	65	100	150	200	150	250	200	165	120
2	60	65	60	70	90	50	40	35	35	20	20	.....
3	50	75	80	60	50	25	20	10	0	0	0	0
4	60	100	65	60	85	40	20	10	5	0	0	0
5	110	100	100	120	120	100	50	40	0	0	0	0
6	50	10	50	25	0	0	0	0	0	0	10	50
7	— 30	— 20	— 40	— 30	— 50	— 60	— 70	— 40	— 80	— 50	— 10	.....
8	100	110	110	130	160	100	100	60	50	150	250	200
9	100	100	150	100	100	100	70	80	120	110	150	— 10
10	50	45	50	40	50	70	100	70	75	120	120	100
11	30	45	65	75	70	25	50	75	110	60	100	150
12	100	100	100	100	80	50	60	60	60	70	60	50
13	100	70	70	40	50	60	— 50	0	100	100	150	140
14	60	50	60	50	50	50	80	80	80	100	100	100
15	0	0	0	0	0	0	0	0	0	0	0	0
16	— 10	— 5	0	0	0	— 20	15	5	0	0	0	0
17	40	20	10	0	0	0	0	0	0	0	0	0
18	30	—200	—100	— 20	20	60	— 60	—150	—200	—300	—200	—200
19	100	150	160	175	150	150	130	190	120	120	100	100
20	85	65	80	100	140	160	150	120	100	100	100	100
21	0	120	120	100	130	150	160	160	160	150	150	150
22	40	50	70	70	60	70	100	100	100	20	.....	.....
23	40	50	50	50	50	50	60	50	60	60	90	90
24	20	75	100	105	60	75	80	80	120	120	130	150
25	0	0	0	0	0	0	0	0	0	0	0	0
26	60	60	60	65	60	60	65	70	65	85	60	50
27	150	120	200	130	120	160	145	200	150	200	200	.....
28	90	80	85	80	60	80	100	90	80	50	0	100
29	40	40	50	60	60	80	110	130	120	100	100	100
30	100	— 10	120	150	150	150	150	100	90	100	60	0
31	—250	—400	—300	—250	0	20	20	20	50	65	10	0
Sums	1,595	1,155	1,710	1,720	2,065	2,005	1,895	1,795	1,820	1,750	1,915	1,540
Means	55	40	61	64	79	74	70	66	76	76	83	86

***registration, at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.**

NOVEMBER, 1886.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
140	150	130	130	140	155	110	110	110	100	95	100	NW. fr., clear.
100	300	260	270	240	240	220	150	175	140	110	130	Var. gen., clear.
140	200	250	175	140	120	100	100	80	80	80	60	S. lt., fair.
100	120	125	120	170	120	150	120	80	100	100	100	NW. fr., fair.
120	150	200	150	80	60	65	60	65	90	80	40	Var. lt., fair.
140	50	— 5	— 50	—250	— 60	— 20	—200	—100	200	50	— 10	NW. br., rain.
.....	.....	90	100	65	70	70	70	70	65	60	60	Do.
50	65	45	55	50	50	60	70	100	90	100	60	NW. high, clear.
100	95	150	180	120	230	160	180	190	100	75	75	NW. fr., clear.
130	160	150	190	160	180	110	100	75	75	90	110	S. fr., rain.
60	75	75	75	75	100	50	110	60	60	60	40	NW. fr., cloudy.
—200	—200	—200	—170	— 60	150	—200	—200	—400	—300	— 50	0	N. fr., rain.
0	25	50	60	30	40	30	30	30	25	25	25	NW. high, snow.
.....	.....	75	60	60	65	65	50	50	40	30	50	NW. br., clear.
60	45	50	90	60	50	45	30	25	30	50	40	NW. fr., clear.
105	120	210	160	190	220	160	100	60	60	70	45	N. fr., fair.
75	110	70	50	90	50	50	40	30	20	10	10	NE. lt., rain.
60	60	60	65	50	50	50	50	55	100	110	120	SE. br., rain.
45	60	60	50	55	55	75	60	70	90	100	105	W. br., clear.
100	75	60	50	65	80	80	80	90	110	110	100	SW. fr., fair.
.....	.....	140	150	105	150	100	100	100	95	90	100	Var. fr., fair.
140	140	100	100	30	— 10	25	50	50	50	0	— 25	N. lt., rain.
60	100	110	100	120	100	100	60	0	50	60	60	SW. br., rain.
90	100	100	120	100	75	90	90	85	90	60	60	Do.
65	—100	—400	—300	—400	—250	20	50	50	50	50	50	NW. high, rain.
100	100	120	120	120	100	110	100	110	120	160	165	NW. br., clear.
100	75	65	75	75	100	110	80	140	80	100	110	NW. fr., clear.
.....	.....	140	160	100	100	120	120	140	200	190	120	S. lt., clear.
100	130	150	110	110	190	175	190	85	50	50	100	SW. lt., fair.
100	—200	60	75	100	130	135	120	95	95	95	100	E. fr., rain.
2,080	2,005	2,490	2,520	1,990	2,710	2,415	2,070	1,770	2,155	2,210	2,100	
80	77	83	84	66	90	80	69	59	72	73	70	

DECEMBER, 1886.

120	100	100	95	100	100	80	85	85	85	85	60	NW. fr., cloudy.
— 50	20	25	50	50	60	60	50	50	50	60	50	NW. high, fair.
5	20	25	30	30	60	50	55	60	60	65	70	Do.
0	10	50	55	50	50	30	60	40	100	65	— 20	N. br., snow.
200	50	— 50	— 20	—100	— 60	— 50	10	20	50	50	50	NE. fr., snow.
65	100	60	60	20	50	0	0	0	0	— 5	— 30	NW. fr., snow, rain.
100	100	100	75	90	105	90	110	110	90	100	100	NE. br., snow.
190	160	150	150	160	240	200	200	160	100	130	100	W. fr., clear.
0	200	200	210	200	100	75	80	80	100	60	60	Var. lt., clear.
150	160	165	165	165	60	50	50	— 50	0	0	40	Do.
160	240	200	160	130	110	140	100	100	100	90	100	Var. lt., fair.
.....	.....	60	.....	100	140	100	75	75	5	15	100	Var. lt., rain.
140	100	150	170	130	200	180	170	160	160	200	140	Var. fr., rain.
.....	.....	.....	100	60	180	205	160	60	40	20	0	SW. br., cloudy.
—200	60	70	— 50	300	250	—100	—200	160	150	0	— 20	Var. fr., rain, snow.
— 50	—100	60	50	65	110	110	90	60	60	50	50	NW. br., snow.
.....	.....	.....	.....	.....	.....	80	80	90	60	60	60	SW. fr., cloudy.
—100	— 20	— 80	—300	—100	—200	100	60	100	100	120	130	SW. fr., rain.
.....	.....	100	110	110	120	120	90	130	110	130	90	NW. gen., fog, fair.
.....	.....	.....	.....	100	150	110	130	130	100	100	— 10	NW. fr., clear.
130	160	200	200	120	120	100	100	100	60	60	40	Var. lt., clear.
.....	.....	.....	—100	—160	— 50	0	50	50	50	30	20	NW. gen., rain.
60	100	50	50	30	60	80	70	60	50	60	25	NE. fr., rain.
100	120	120	100	120	100	0	—210	—200	0	0	0	Var. fr., rain.
0	65	80	80	75	75	50	85	120	100	60	65	NW. br., clear.
.....	.....	.....	100	200	— 20	0	0	0	200	160	200	NE. fr., snow.
120	100	130	100	85	85	80	65	100	110	110	100	NW. fr., fair.
120	110	110	100	150	160	120	120	160	150	100	60	Var. lt., cloudy.
100	100	100	100	95	80	75	50	20	30	— 20	120	N. fr., snow.
10	50	10	10	20	50	0	— 10	— 5	— 50	20	25	NE. fr., snow.
0	— 5	60	75	40	40	60	—400	300	300	300	—450	NE. fr., snow, rain.
1,370	2,000	2,245	1,925	2,435	2,525	2,195	1,375	2,325	2,520	2,275	1,325	
69	83	86	69	81	84	71	44	75	84	76	46	

TABLE A.—*Hourly records, drawn from continuous photographic*

JANUARY, 1887.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	150	—100	100	120	130	100	—300	—150	0	0	60	50
2	0	0	0	0	0	0	0	0	0	0	0	0
3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	120
9	150	120	120	120	120	125	135	100	70	70	60	60
10	135	100	125	130	150	155	195	100	70	60	0	— 20
11	90	110	105	105	80	60	50	40	30	20	30	0
12	110	100	95	120	60	90	110	110	120	120	120	.....
13	200	300	200	160	240	160	175	150	290	250	200	200
14	—250	—100	50	45	0	100	100	140	150	120	100	.....
15	270	260	250	230	140	170	90	60	50	40	40	.....
16	100	140	175	160	110	120	120	125	125	120	125	.....
17	95	95	90	70	85	100	60	60	75	10	10	— 50
18	95	95	95	90	90	100	50	40	35	30	20	.....
19	30	30	25	25	25	25	40	30	20	5	0	.....
20	120	110	100	100	100	110	140	150	160	100	100	150
21	75	20	25	20	25	40	90	65	50	50	0	0
22	20	110	25	0	30	20	20	50	50	60	80	50
23	70	50	60	55	50	45	30	15	5	0	0	.....
24	140	65	205	300	100	100	— 60	—300	—300	—200	—400	0
25	120	120	130	140	170	210	220	210	190	160	140	100
26	80	80	80	95	100	105	100	— 50	— 50	40	45	40
27	90	80	75	50	25	15	10	5	0	0	0	140
28	100	80	100	110	90	100	110	100	110	100	100	100
29	75	75	60	100	100	100	70	35	— 50	—200	300	200
30	130	130	125	100	100	100	150	100	100	140	60	.....
31	100	120	130	110	110	135	100	100	110	110	120	140
Sums	2,295	2,190	2,555	2,555	2,230	2,385	1,805	1,285	1,410	1,205	1,310	1,280
Means	96	91	106	106	93	99	75	54	61	55	59	85

FEBRUARY, 1887.

1	70	90	90	80	85	110	50	90	90	95	110	.....
2	40	25	30	100	100	—300	— 50	— 50	— 25	0	0	0
3	55	45	0	— 10	25	85	125	200	165	145	175	150
4	10	0	0	0	0	0	0	0	0	0	0	0
5	80	70	75	65	60	70	70	60	100	90	60	70
6	50	25	35	10	20	20	60	100	80	85	50	.....
7	0	0	0	0	0	0	0	0	0	0	0	0
8	85	80	70	50	60	85	100	110	75	100	150	.....
9	60	45	60	50	50	50	50	55	55	35	30	60
10	120	160	165	125	150	140	120	130	150	180	100	60
11	50	25	30	40	20	20	25	40	40	40	0	50
12	25	40	50	40	60	60	65	40	0	0	0	0
13	40	40	40	40	20	20	10	0	0	0	0	0
14	105	110	100	80	65	90	130	160	100	70	50	.....
15	—350	—250	—200	—150	—200	— 20	25	— 20	— 30	— 25	— 30	— 30
16	10	10	50	0	30	60	— 20	60	50	50	100	90
17	30	40	50	70	70	100	100	80	80	60	60	50
18	50	75	50	55	40	45	— 20	0	0	0	— 20	.....
19	30	0	0	0	25	30	50	60	50	50	50	50
20	70	75	90	60	60	60	60	90	80	80	80	100
21	60	60	60	60	100	90	100	180	160	120	120	100
22	80	80	80	60	70	80	60	100	90	50	50	60
23	70	70	65	50	50	80	50	90	90	100	100	.....
24	— 50	—250	— 20	50	40	60	60	50	70	85	80	80
25	70	75	80	80	100	100	110	100	90	110	100	.....
26	120	120	130	140	300	0	300	—300	100	100	0	0
27	70	70	70	65	70	80	80	100	80	90	80	70
28	60	65	70	60	40	25	20	20	20	10	10	100
Sums	1,110	995	1,320	1,270	1,510	1,240	1,730	1,545	1,760	1,720	1,505	1,140
Means	41	38	51	49	58	48	67	59	73	75	65	71

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

JANUARY, 1887.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
60	90	80	80	70	60	55	50	50	50	50	30	NW. br., rain, snow.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. br., clear.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Do.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. lt., cloudy.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	N. lt., snow.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	N. lt., fair.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW. lt., cloudy.
120	120	135	140	120	160	145	130	150	160	160	175	NE. fr., clear.
60	160	140	120	130	125	100	85	100	110	120	150	NE., fr., snow, sleet.
— 15	20	— 30	25	25	20	5	60	60	75	105	100	NW. br., snow, clear.
150	130	125	100	175	140	140	145	150	130	100	110	NW. fr., cloudy.
.....	160	200	130	175	200	250	300	300	150	210	240	SW. fr., fair.
160	190	160	100	85	60	65	—300	— 50	20	40	—300	Var. lt., rain.
150	290	175	200	220	190	160	220	200	280	260	220	Var. lt., rain, fog.
.....	120	140	150	125	125	100	100	100	85	100	100	NW. br., fog, fair.
.....	.....	150	200	140	125	100	120	140	90	95	100	Var. fr., cloudy.
140	50	100	—200	— 50	60	60	70	75	75	75	75	Var. lt., rain.
50	75	40	40	45	90	60	50	30	20	30	30	NW. high, clear.
60	65	70	80	75	75	80	80	90	90	95	100	NW. fr., cloudy.
190	210	120	80	95	110	100	100	70	75	80	50	Var. fr., cloudy.
30	60	60	10	50	40	25	— 60	85	60	45	30	SW. fr., cloudy.
100	130	155	105	110	80	20	50	60	70	95	60	SW. fr., fair.
.....	60	110	150	180	160	160	120	140	140	120	145	S. br., fair.
—200	150	100	60	80	85	100	80	95	80	75	100	NW. br., rain, snow.
140	140	60	10	0	0	0	0	0	80	75	70	NW. br., fair.
0	80	100	180	140	120	90	95	140	100	140	120	W. br., rain, snow.
250	250	220	240	180	130	130	130	100	100	80	80	NW. fr., clear.
105	130	145	110	200	160	90	95	105	100	110	90	SW. br., cloudy.
—400	—300	—300	—200	— 50	50	50	30	25	60	95	140	SW. fr., rain.
.....	.....	160	150	140	120	120	120	90	150	160	140	W. fr., cloudy.
155	145	115	105	100	85	85	75	80	150	140	100	E. fr., clear.
1,305	2,525	2,530	2,165	2,560	2,570	2,290	1,945	2,385	2,500	2,655	2,255	
65	110	101	87	102	103	89	78	55	100	105	90	

FEBRUARY, 1887.

.....	110	100	60	30	60	65	50	50	55	60	45	Var. fr., cloudy. [rain.
25	30	10	60	90	100	—100	— 60	50	10	100	50	NE. fr., snow, sleet,
100	160	75	—200	185	140	130	105	95	60	25	20	Var. lt., rain.
90	90	95	90	100	100	100	100	130	150	130	105	NW. fr., cloudy.
70	115	55	— 40	20	25	60	40	40	45	40	50	N. fr., snow, sleet, rain.
.....	140	160	190	175	140	100	50	10	0	0	0	N. fr., rain.
100	100	100	70	95	150	25	50	60	50	95	100	NE. fr., rain, fog.
75	110	50	100	130	120	10	— 10	150	120	60	70	E. lt., rain, fog.
60	75	50	55	45	70	80	65	90	80	110	110	NW. fr., fair.
60	100	95	110	100	— 60	—150	75	70	60	40	60	Var. lt., rain.
40	0	0	0	0	0	0	0	0	0	0	40	NW. high, rain.
40	55	40	40	45	45	40	40	50	50	50	50	NW. br., cloudy.
50	55	55	55	60	50	65	70	60	60	80	80	NW. fr., clear.
100	105	125	80	60	70	90	40	40	25	10	—100	NE. fr., snow, rain.
50	70	100	100	60	40	50	— 25	5	70	90	0	NE. fr., rain.
100	95	95	100	70	40	50	50	40	35	40	30	NE. fr., cloudy.
50	50	60	50	120	100	100	75	25	60	50	60	NW. lt., clear.
—150	10	60	20	200	— 10	—200	0	30	40	50	30	SW. fr., rain, t. s.
60	50	50	50	40	70	60	50	60	50	50	60	NW. fr., clear. [sleet.
.....	300	70	40	60	100	200	50	100	120	60	50	NE. fr., rain, snow,
60	65	90	150	140	150	120	60	60	70	80	80	E. fr., rain.
55	70	60	60	60	70	60	50	65	60	70	70	Var. lt., fair.
200	180	190	180	190	140	80	60	100	60	70	100	Var. lt., snow, rain.
60	80	85	80	70	60	60	60	60	60	60	70	SW. NW. br., rain.
75	90	60	80	65	100	100	140	75	140	120	100	NW. fr., fair.
—200	20	—175	— 50	200	150	0	—100	— 50	50	40	70	N. fr., snow, rain.
75	60	55	60	40	50	60	100	80	50	50	60	NW. gale, clear.
90	70	70	70	70	70	70	70	70	70	80	95	NW, high, clear.
1,335	2,455	1,880	1,660	2,520	2,140	1,325	1,255	1,685	1,700	1,710	1,555	
53	91	70	61	93	79	49	49	62	66	67	60	

TABLE A.—*Hourly records, drawn from continuous photographic*

MARCH, 1887.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	100	55	70	60	100	60	140	100	160	180	70	50
2	35	35	40	40	25	40	80	65	60	5	20	50
3	40	30	30	25	25	25	45	50	25	30	20	25
4	0	0	0	0	0	0	0	0	0	0	0	0
5	30	60	50	50	50	60	75	60	70	70	75	65
6	— 50	0	50	100	150	60	110	150	105	75	20	50
7	100	100	75	75	20	— 50	100	0	0	0	150	120
8	150	100	140	150	130	150	150	125	120	100	100	100
9	50	50	60	70	100	100	100	150	150	200	200	150
10	75	60	75	50	50	100	75	75	50	50	50	50
11	65	50	50	50	60	80	60	50	60	50	45	50
12	50	50	50	50	50	50	0	— 80	— 80	— 40	20	25
13	90	100	100	100	100	150	150	90	100	100	100	100
14	0	50	50	25	25	25	5	10	50	50	60	50
15	40	40	50	55	55	70	50	50	50	40	40	50
16	45	40	50	50	55	55	50	0	0	5	0	5
17	60	60	60	60	70	90	85	0	0	60	75	100
18	60	60	50	50	50	60	125	200	100	40	50	100
19	60	60	60	50	50	50	50	50	50	50	25	25
20	40	45	40	45	50	55	60	65	50	50	50	50
21	110	110	120	110	100	150	150	75	200	200	200	220
22	0	0	200	200	200	—400	300	—400	0	—100	50	60
23	50	60	50	40	40	55	50	50	60	60	60	60
24	60	80	70	60	70	50	50	50	50	100	.....	.....
25	50	50	50	50	50	50	50	50	25	20	0	45
26	70	50	60	40	40	50	50	50	50	40	50	50
27	30	30	25	25	20	25	25	25	25	40	25	.....
28	0	0	—300	0	50	40	50	70	70	80	60	60
29	50	30	20	40	50	40	40	— 70	— 10	— 20	10	70
30	50	50	50	50	70	70	70	60	70	60	60	60
31	100	100	60	60	50	10	10	—100	—100	— 50	—100	100
Sums	1,610	1,605	1,555	1,890	1,955	1,390	2,345	1,070	1,560	1,545	1,605	1,940
Means	54	54	52	63	65	46	78	36	52	52	55	69

APRIL, 1887.

1	— 50	— 25	— 15	— 20	— 10	— 50	— 5	20	10	0	0	— 10
2	100	100	100	100	100	100	110	110	70	80	60	70
3	60	60	60	40	40	50	60	60	50	50	60	60
4	30	40	30	30	15	50	— 5	10	25	20	— 10	0
5	10	25	25	30	40	40	30	0	10	0	10	10
6	50	50	60	55	60	60	60	60	60	60	60	60
7	10	25	40	20	— 5	10	5	0	10	0	20	20
8	25	25	50	20	30	30	30	20	40	60	90	90
9	30	40	50	50	50	50	50	40	50	75	100	100
10	50	30	0	30	40	40	25	30	30	15	30	30
11	40	50	50	50	100	70	50	70	60	15	25	30
12	10	20	20	20	10	5	10	20	50	80	80	85
13	20	10	10	20	15	10	0	0	20	30	50	30
14	0	10	0	10	5	10	100	100	100	80	105	80
15	10	20	15	40	20	10	10	60	50	60	60	50
16	— 50	— 50	50	20	50	— 50	— 20	10	10	10	10	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	20	20	20	— 15	—100	— 70	— 20	20	20	0	0	—200
19	0	5	— 5	0	50	50	50	50	50	40	40	60
20	70	90	80	60	80	70	90	90	90	70	70	70
21	50	50	50	40	50	50	50	50	100	105	110	150
22	50	50	25	60	40	50	70	90	70	70	60	60
23	30	30	10	30	60	60	0	90	100	60	80	80
24	40	40	40	50	50	50	60	60	60	60	60	.....
25	50	70	100	100	100	120	100	80	100	100	150	130
26	50	— 50	—300	30	50	90	60	60	60	65	65	70
27	80	90	50	50	—100	— 10	20	60	70	70	60	60
28	50	70	80	70	30	70	100	100	150	120	130	80
29	30	40	40	40	40	50	50	20	20	30	0	— 20
30	20	25	50	50	50	50	60	60	50	50	30	30
Sums	885	960	785	1,080	960	1,115	1,205	1,440	1,585	1,470	1,605	1,275
Means	31	33	27	37	33	38	42	50	55	51	55	46

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

MARCH, 1887.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
90	65	70	100	120	70	60	70	50	60	60	50	Var. lt., cloudy.
40	60	50	80	80	30	60	60	30	60	40	40	E. lt., cloudy.
10	25	20	20	0	15	25	15	0	0	0	0	E. lt., rain, sleet.
100	60	40	65	70	70	80	15	10	60	60	20	NE. br., rain, snow.
100	50	— 75	—100	—200	—150	0	50	50	25	40	50	E. fr., snow, sleet, rain.
.....	80	20	15	40	—100	50	60	150	150	100	110	Var. lt., rain.
80	150	150	150	150	150	140	80	150	175	200	200	Do.
100	100	100	90	100	100	90	75	120	80	70	10	Var. lt., clear.
0	—200	—175	5	—100	—100	0	— 75	— 50	0	50	25	E. lt., rain.
50	65	60	60	50	60	50	50	70	90	50	50	NW. br., rain, clear.
45	50	45	45	50	50	50	50	55	45	40	45	NW. br., clear.
50	50	50	50	50	50	50	50	50	60	60	70	Do.
.....	100	75	80	80	80	75	90	80	—400	—400	50	Var. lt., rain.
40	55	65	50	0	50	50	40	50	40	40	40	NW. br., cloudy.
50	45	50	60	60	50	50	50	50	50	45	45	Do.
— 20	25	25	25	0	50	50	50	50	50	50	60	NW. fr., fair.
50	100	100	50	50	50	100	60	150	170	170	170	NW. br., snow.
50	40	50	20	20	50	50	50	50	50	50	50	NW. fr., cloudy.
50	50	50	50	50	25	30	40	50	45	45	50	NW. lt., cloudy.
.....	100	100	100	100	100	110	115	120	100	100	120	NW. fr., fair.
120	100	200	200	200	—250	—200	—200	—250	0	—300	0	N. fr., rain, snow.
45	60	50	50	50	50	50	50	60	45	45	55	NW. high, snow, rain.
45	65	60	50	50	50	70	60	65	60	50	50	NW. br., fair.
100	220	180	160	100	80	90	80	60	50	50	45	Var. lt., rain.
45	50	60	50	50	60	60	60	90	50	100	50	NW. br., fair.
50	50	50	65	50	25	50	50	40	20	30	40	N. fr., fair.
.....	50	40	— 20	30	40	— 20	100	70	—200	—300	0	E. fr., rain.
90	40	25	100	—100	50	50	50	40	40	50	50	NNW. fr., rain, snow.
— 20	— 5	15	— 15	— 5	— 10	50	40	40	50	20	50	NW. high, cloudy.
50	50	45	40	40	40	60	60	70	60	75	100	NW. fr., fair.
—100	150	150	0	0	100	100	120	80	120	100	60	NW. fr., snow.
1,310	1,900	1,745	1,695	1,235	935	1,530	1,465	1,650	1,205	790	1,705	
49	61	56	55	40	30	49	47	55	40	26	57	

APRIL, 1887.

— 20	40	40	70	70	50	50	90	60	40	60	100	NW. fr., snow.
70	70	60	60	40	50	50	70	40	20	50	60	NW. fr., snow, fair.
.....	60	60	65	80	80	80	50	50	50	50	25	SW. fr., clear.
5	5	0	5	5	10	0	5	30	30	— 50	—300	SW. br., rain.
0	— 5	— 5	10	— 10	5	50	25	50	50	50	50	NW. br., snow.
60	60	50	45	40	30	40	100	100	60	50	— 5	NW. br., fair.
0	25	25	25	0	50	20	60	50	50	10	25	E. lt., cloudy.
100	110	90	90	100	80	90	70	45	45	50	25	Do.
100	120	150	140	90	50	50	30	30	50	40	50	Var. lt., clear.
.....	60	60	50	60	50	50	50	60	40	40	40	Do.
60	65	50	50	30	30	30	20	20	25	15	10	W. fr., clear.
65	110	120	100	90	75	80	50	50	25	25	25	E. lt., clear.
40	30	40	60	30	20	20	10	20	20	5	10	E. lt., fair.
90	120	105	50	105	105	60	40	10	10	20	10	SE. lt., fair.
60	100	100	80	70	70	25	— 20	—100	—100	—300	—250	SE. fr., rain, t. s.
0	— 5	— 20	— 10	— 5	0	10	10	0	0	0	0	NW. br., rain.
50	40	40	50	40	30	30	30	30	15	— 10	5	NW. fr., rain.
—350	0	10	10	—200	200	50	0	0	0	10	0	NE. fr., rain.
15	30	40	50	60	60	80	100	120	100	110	100	N. fr., rain.
60	120	100	140	120	80	70	90	130	100	100	50	N. lt., fair.
100	150	120	150	150	100	80	60	70	50	50	90	S. lt., clear.
80	70	120	—150	—150	—300	—200	— 50	0	10	10	20	Var. lt., rain.
60	50	80	70	40	100	— 70	40	40	—100	50	40	SE. fr., rain.
.....	100	100	90	80	100	100	105	100	100	60	60	NW. fr., clear.
100	— 50	— 50	—100	—250	—300	—300	200	—150	—100	— 10	—100	NE. fr., rain.
70	80	70	60	70	50	50	50	60	50	50	60	W. fr., rain.
60	60	60	60	170	50	50	100	100	100	30	40	Var. lt., rain.
100	120	—200	—100	—100	0	10	30	40	30	40	30	S. fr., rain.
20	20	20	30	30	30	—100	0	— 10	10	10	20	NW. br., rain.
0	20	25	— 50	— 20	— 20	50	50	60	60	40	40	NW. br., cloudy.
995	1,775	1,420	1,200	835	935	605	1,515	1,105	840	645	330	
37	59	47	40	28	31	20	50	38	29	22	11	

TABLE A.—*Hourly records, drawn from continuous photographic*

MAY, 1887.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	55	60	50	55	60	65	80	90	90	90	100	100
2	50	60	30	50	50	50	60	65	90	.....	100	100
3	0	10	10	10	0	0	0	0	5	— 10	120	110
4	10	10	15	15	15	10	5	0	5	10	10	10
5	5	0	0	0	0	0	20	30	80	100	100	60
6	10	10	15	10	0	15	0	5	10	15	70	75
7	15	15	— 50	70	— 10	— 20	— 20	15	30	20	30	50
8	10	10	10	— 10	— 5	10	30	—100	— 70	— 60	15	— 20
9	40	70	0	10	— 10	20	70	— 50	—100	60	0	.....
10	65	60	65	50	50	15	25	35	100	10	0	.....
11	10	100	120	150	110	110	100	100	100	60	60	.....
12	0	0	0	0	0	0	0	0	0	60	120	150
13	10	20	20	15	— 5	0	0	0	— 5	— 50	60	70
14	20	0	10	30	30	20	20	15	20	20	20	60
15	30	20	20	15	15	20	20	10	10	10	20	20
16	5	5	5	0	0	0	0	5	70	80	80	0
17	— 5	0	0	0	0	0	— 10	— 50	— 60	0	110	100
18	10	10	40	20	35	20	10	30	30	0	10	10
19	10	10	10	10	5	5	10	5	10	10	10	5
20	20	30	40	40	35	50	50	90	90	75	70	0
21	60	60	60	75	80	90	80	80	80	60	70	70
22	20	20	40	40	30	50	50	60	60	60	60	60
23	90	90	90	90	90	90	60	50	70	70	70	70
24	50	30	50	30	35	35	35	35	40	— 50	— 50	100
25	50	40	30	30	30	60	60	60	60	50	50	50
26	50	50	60	50	100	105	60	20	30	60	60	60
27	40	20	20	30	30	30	40	40	80	60	40	30
28	40	50	55	55	50	25	20	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0
30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
31	105	80	100	70	80	60	70	60	.....	.....	.....	.....
Sums	875	945	915	1,010	900	935	945	700	925	810	1,405	1,340
Means	31	34	33	36	32	33	34	26	36	31	52	56

JUNE, 1887.

1	—220	— 50	0	10	30	30	100	120	120	80	70	90
2	60	70	85	80	70	—150	70	120	100	110	150	60
3	0	0	0	60	70	70	40	50	60	70	80	.....
4	50	50	50	50	60	70	70	50	40	40	40	40
5	70	100	50	50	50	50	60	65	60	60	70	70
6	55	60	60	60	30	30	70	—350	—300	—150	.....	100
7	10	20	0	— 20	— 30	0	— 10	— 40	20	20	10	0
8	40	30	30	40	50	30	40	100	100	70	110	120
9	80	80	60	40	55	55	50	50	40	40	30	40
10	30	20	40	60	50	50	50	60	.....	.....	.....	60
11	50	50	50	10	60	60	50	60	40	— 60	— 60	— 10
12	50	50	40	30	30	30	30	30	20	20	20	.....
13	70	60	60	50	60	70	60	50	35	0	15	20
14	0	0	0	— 10	20	30	0	0	20	— 10	— 10	50
15	0	0	0	0	10	20	50	40	50	50	50	40
16	90	90	60	60	60	60	70	60	50	60	60	60
17	30	10	0	0	0	10	0	0	0	— 10	— 20	— 30
18	10	40	60	50	60	50	40	30	40	50	50	.....
19	15	0	20	50	30	40	80	70	50	50	40	.....
20	80	80	90	70	110	160	110	110	80	200	100	.....
21	70	60	100	130	130	120	130	110	210	180	180	130
22	200	60	70	80	80	80	80	110	120	50	60	70
23	—175	— 5	40	50	60	110	110	100	100	170	200	160
24	100	70	70	80	70	110	105	90	105	80	70	50
25	30	40	40	40	50	60	60	50	65	50	60	75
26	60	70	65	75	60	70	80	90	75	60	60	.....
27	10	10	15	10	10	30	50	50	50	30	40	40
28	75	75	70	50	65	80	80	60	60	60	40	60
29	50	60	60	50	45	40	55	60	65	60	60	50
30	50	50	40	40	60	50	70	50	50	80	80	80
Sums	1,035	1,250	1,325	1,345	1,505	1,515	1,850	1,495	1,525	1,520	1,655	1,465
Means	34	42	44	45	50	50	62	50	53	52	59	61

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

MAY, 1887.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
70	90	100	65	65	60	60	60	80	80	60	60	Var. lt., rain.
100	100	100	100	110	70	40	35	35	20	20	20	SE. fr., fair.
70	105	110	50	25	0	50	50	50	— 10	10	10	Do.
5	15	100	100	110	120	50	10	15	15	25	5	SE. fr., fair, lightning.
75	120	25	25	25	25	— 10	— 10	10	10	10	10	E. lt., rain.
90	110	60	0	—300	70	40	50	30	10	0	10	SE. fr., rain, t. s.
0	150	60	70	—200	— 50	10	15	30	25	0	10	SW. fr., rain, t. s.
.....	200	—100	—200	60	—100	—200	— 5	0	0	15	15	NE. fr., rain, t. s.
80	30	45	15	90	100	100	20	50	50	50	65	E. fr., rain.
100	100	110	110	90	75	80	90	90	70	100	100	Do.
.....	200	105	0	150	70	80	65	60	0	0	0	SE. fr., clear.
150	160	80	60	30	100	100	10	— 10	10	30	15	E. fr., clear.
70	160	170	170	150	0	— 50	— 50	0	0	25	40	Do.
100	100	100	90	90	70	70	100	30	30	30	40	NE. fr., clear.
5	10	30	30	60	60	60	65	10	5	10	10	SE. fr., clear.
100	160	90	105	110	60	50	— 20	5	0	0	0	SE. lt., clear.
110	160	100	130	80	25	0	10	0	60	— 20	10	NE. fr., hazy.
10	10	100	130	150	130	70	50	50	10	30	10	NE. fr., cloudy.
10	100	100	120	120	80	60	50	10	20	20	20	E. lt., clear.
0	0	0	0	0	60	70	70	60	75	75	50	Var. lt., hazy.
80	105	105	70	80	60	50	50	50	30	30	30	Var. lt., cloudy.
35	60	65	70	60	60	70	80	90	80	90	80	Var. lt., fog, clear.
100	130	110	75	90	50	50	50	50	50	50	50	S. lt., fair.
110	150	100	100	—200	—300	—200	60	0	50	50	70	Var. lt., rain.
105	180	180	110	—300	100	0	80	60	60	50	40	Var. br., rain, t. s.
50	60	70	50	200	0	— 30	60	40	40	50	70	NW. br., rain, t. s.
50	40	40	60	150	50	50	50	50	50	45	40	NW. fr., rain.
0	0	0	0	0	0	0	0	0	0	0	0	Do.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	N. fr., fair.
220	275	230	210	170	140	140	120	150	150	130	110	SE. fr., clear.
60	100	100	80	80	— 50	—100	—250	—300	—250	—300	— 50	E. br., rain.
1,955	3,170	2,485	1,995	2,420	1,135	760	965	795	740	685	940	
72	109	86	69	83	39	26	33	27	26	24	32	

JUNE, 1887.

110	130	160	200	180	110	100	80	70	70	60	60	Var. lt., rain, lightning.
150	120	110	170	160	120	200	—300	100	—300	60	70	SW. br., rain, t. s.
40	55	50	45	65	65	60	60	50	50	50	40	NW. fr., rain.
30	70	50	50	20	40	100	100	100	100	70	70	NW. fr., fair.
70	70	60	65	50	40	40	35	40	30	50	50	E. fr., cloudy.
60	120	110	110	120	90	85	60	65	40	50	—150	E. fr., rain.
50	35	40	40	55	50	55	50	60	50	25	60	Do.
80	90	100	120	80	80	80	100	80	80	80	80	Var. lt., cloudy.
50	60	—200	— 70	0	100	20	50	50	50	40	40	W. fr., cloudy, t. s.
40	100	100	90	70	50	50	50	60	50	50	40	NE. fr., cloudy.
— 20	— 50	20	50	50	50	60	40	60	40	30	50	E. br., clear.
.....	50	50	70	40	50	30	30	60	50	70	70	NE. fr., clear.
20	20	35	40	20	40	40	50	50	30	20	10	N. fr., clear.
50	50	40	40	140	110	70	60	40	50	40	10	NE. lt., clear.
60	70	150	160	130	110	90	90	130	100	100	100	E. fr., clear.
50	70	80	60	50	45	60	50	— 10	10	20	50	SW. lt., clear.
— 20	— 5	— 5	0	— 10	0	5	10	10	0	10	0	W. lt., fair, lightning.
30	40	40	—200	—200	— 10	20	— 5	10	0	0	—110	Var. br., rain, hail, t. s.
.....	150	150	150	160	100	70	200	200	160	80	70	Var. br., rain, t. s.
90	100	120	110	130	200	200	150	120	100	80	70	W. br., rain, t. s.
100	155	200	140	115	120	0	10	30	50	—100	0	S. br., rain, t. s.
60	200	—200	60	70	110	300	—200	300	0	—200	—200	Var. br., rain, t. s.
100	140	160	160	200	180	205	150	160	120	125	105	Var. lt., rain.
70	80	90	70	60	50	60	50	50	30	25	20	W. fr., fair.
70	100	105	110	80	60	75	100	30	60	60	60	N. fr., fair.
.....	70	50	60	70	70	25	60	30	30	20	10	Var. lt., fair.
40	60	70	75	120	160	130	160	80	80	80	80	Do.
40	150	80	150	160	140	80	120	90	80	80	60	Do.
0	0	0	0	0	0	60	120	130	80	70	40	SW. fr., clear.
70	90	90	95	80	80	80	80	120	100	100	90	S. lt., clear.
1,490	1,390	1,905	2,215	2,265	2,410	2,450	1,610	2,365	1,390	1,245	945	
55	46	64	74	76	80	82	54	79	47	42	32	

TABLE A.—*Hourly records, drawn from continuous photographic*

JULY, 1887.

Day of month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	100	110	90	90	100	80	100	140	130	125	160	.....
2	90	90	80	80	100	100	110	100	130	160	160	100
3	80	80	80	60	70	65	70	80	60	60	50	50
4	100	90	90	100	100	100	120	130	70	90	90	90
5	60	60	50	—100	—200	—250	—300	—200	150	50	70	70
6	90	70	70	105	100	100	80	100	70	100	120	120
7	105	70	70	70	100	140	70	70	70	65	80	80
8	80	80	70	100	70	70	60	80	100	130	150	150
9	120	90	60	40	50	60	110	100	200	300	300	0
10	100	70	70	80	100	100	90	85	80	80	80	80
11	50	50	50	50	60	70	60	40	40	20	.....	30
12	40	40	50	60	70	90	60	40	60	50	50	50
13	50	50	50	50	40	50	30	40	50	50	50	50
14	40	40	50	50	55	60	50	50	50	50	60	60
15	40	30	50	30	20	30	40	50	60	40	70	75
16	30	30	30	25	40	25	0	0	0	30	30	30
17	30	30	30	30	30	30	25	20	15	10	10	— 5
18	20	30	30	30	30	70	50	20	30	40	0	40
19	— 10	20	200	300	— 10	0	0	— 30	0	0	— 10	— 20
20	0	0	0	0	0	0	0	0	0	80	80	.....
21	70	90	60	60	40	0	60	70	80	200	0	0
22	— 5	— 5	— 10	— 10	— 10	— 15	— 15	— 20	— 20	60	75	.....
23	60	50	50	50	40	0	0	15	10	80	80	.....
24	0	50	60	40	25	20	20	30	30	30	30	30
25	70	75	75	75	75	80	80	50	50	60	200	200
26	80	80	80	70	90	120	100	120	100	100	140	.....
27	60	80	70	100	70	110	110	140	100	100	100	100
28	100	100	40	50	50	50	50	35	30	30	50	40
29	40	40	40	10	30	10	30	30	25	25	70	70
30	40	60	30	30	20	50	15	50	150	190	200	40
31	70	70	80	80	80	100	100	70	70	70	70	70
Sums	1,810	1,810	1,845	1,805	1,435	1,515	1,375	1,505	1,990	2,475	2,605	1,615
Means	60	60	62	60	48	50	46	50	66	80	87	62

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

JULY, 1887.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
200	140	100	150	170	120	120	80	110	105	100	100	S. fr., clear.
100	200	180	150	90	90	80	75	90	80	70	80	Do.
.....	.....	.....	140	110	70	80	80	90	80	80	110	S. fr., fair.
100	105	60	80	90	90	90	70	60	70	60	60	SE. br., fair.
60	0	—200	50	150	120	170	100	—250	100	60	100	NW. fr., rain, t. s.
80	120	250	—250	150	100	90	80	90	90	100	90	S. lt., rain, lightning.
0	0	0	0	0	0	0	0	0	100	70	70	S. fr., rain.
120	160	160	200	200	210	60	100	200	150	110	150	S. fr., cloudy.
100	120	—200	100	140	140	130	110	100	100	110	100	S. fr., rain, t. s.
.....	.....	.....	.....	.....	.....	60	60	50	50	50	50	W. br., clear.
30	30	60	60	60	60	70	80	80	60	50	40	Do.
50	60	60	60	60	60	70	70	120	60	60	50	Do.
50	65	65	70	70	75	80	90	60	65	50	50	W. fr., fair.
50	55	45	10	10	10	30	30	30	40	40	30	Var. fr., clear.
150	120	130	100	150	80	20	50	50	50	35	30	Var. fr., fair.
0	0	0	25	30	20	30	40	40	40	30	30	Var. lt., fair.
0	—300	—300	300	10	10	300	— 5	20	20	30	30	NW. fr., rain, t. s.
40	60	—200	— 50	—300	200	200	—200	0	—150	— 10	— 10	N. fr., rain, t. s.
0	0	0	0	0	0	0	0	0	0	0	0	Var. lt., rain, t. s.
60	60	80	80	100	25	40	40	60	50	60	60	E. fr., rain.
0	70	45	40	40	0	0	0	0	0	0	— 5	Var. lt., rain, t. s.
100	130	130	160	150	100	70	50	50	50	50	60	Var. lt., fair, lightning.
70	140	140	— 20	—300	—200	0	0	0	20	100	—200	S. fr., rain, t. s.
.....	110	110	120	125	90	80	75	—100	75	80	80	SE. fr., rain.
180	240	250	250	250	170	100	100	100	60	60	80	SE. fr., rain, lightning.
150	200	150	0	150	100	—100	0	—300	0	200	50	SE. fr., rain, t. s.
60	130	0	140	150	120	80	140	110	100	100	100	Var. fr., rain.
100	210	160	—300	— 300	130	150	100	50	60	50	50	SE. lt., fog, fair, hazy.
60	100	200	200	200	200	100	60	80	60	70	50	SE. fr., rain, t. s.
100	130	150	150	120	110	90	60	70	100	110	70	S. lt., clear. [ning.
100	110	120	110	110	120	110	100	60	60	100	100	SW. lt., cloudy, light-
2,205	2,855	1,745	1,525	2,275	2,420	2,100	1,940	1,425	1,745	2,065	1,655	
85	106	65	54	81	86	72	67	49	60	71	57	

TABLE A.—*Hourly records, drawn from continuous photographic*

MONTHLY MEANS.

Month.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
January, 1885	48	57	49	62	58	59	58	42	32	30	29	31
February, 1885	55	39	27	25	18	30	33	45	28	36	28	40
March, 1885	26	22	33	18	34	38	32	37	21	37	48	39
April, 1885	31	35	37	48	39	46	46	45	44	53	54	64
May, 1885	18	22	37	20	17	14	15	12	17	6	19	29
June, 1885	45	47	43	41	44	44	51	55	60	52	57	51
July, 1885	37	39	38	35	50	52	45	50	48	45	51	53
August, 1885	31	56	49	47	49	63	57	45	40	45	50	50
September, 1885	46	58	56	52	56	68	62	69	65	67	66	68
October, 1885	38	40	40	40	39	52	33	29	48	68	57	71
November, 1885	42	58	48	52	54	74	92	79	84	79	75	64
December, 1885	68	73	65	68	53	47	70	56	58	56	55	29
Sums	495	546	522	508	511	587	594	564	545	574	589	589
Means	41	46	44	42	43	49	50	47	45	48	49	49
January, 1886	79	44	48	50	63	57	63	78	86	78	45	64
February, 1886	62	76	85	77	70	56	64	58	59	52	42	45
March, 1886	29	38	40	34	32	25	21	29	14	14	11	13
April, 1886	22	39	21	19	30	32	30	34	25	34	47	55
May, 1886 *	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
June, 1886*	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
July, 1886	41	42	45	55	49	34	24	44	38	35	28	48
August, 1886	55	50	52	36	38	50	38	48	52	52	51	52
September, 1886	38	42	43	18	42	32	46	57	53	62	60	43
October, 1886	27	37	21	23	44	49	38	53	52	52	53	60
November, 1886	67	76	67	60	70	76	75	90	100	96	100	89
December, 1886	55	40	61	64	79	74	70	66	76	76	83	86
Sums	475	484	483	436	517	485	469	557	555	551	520	555
Means	48	48	48	44	52	48	47	56	56	55	52	56
January, 1887	96	91	106	106	93	99	75	54	61	55	59	85
February, 1887	41	38	51	49	58	48	67	59	73	75	65	71
March, 1887	54	54	52	63	65	46	78	36	52	52	55	69
April, 1887	31	33	27	37	33	38	42	50	55	51	55	46
May, 1887	31	34	33	36	32	33	34	26	36	31	52	56
June, 1887	34	42	44	45	50	50	62	50	53	52	59	61
July, 1887	60	60	62	60	48	50	46	50	66	80	87	62
Sums	347	352	375	396	379	364	404	325	396	396	432	450
Means	50	50	54	57	54	52	58	46	57	57	62	64

* No record.

registration, at Baltimore, Md., 1885, 1886, *and* 1887—Continued.

MONTHLY MEANS.

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Means.
59	89	96	93	87	66	77	78	76	54	52	54	60
65	77	72	73	64	49	39	45	44	52	83	55	47
31	32	41	29	41	16	12	19	25	24	29	25	30
67	67	55	37	45	33	22	48	31	34	22	22	43
44	60	70	79	51	49	44	38	34	35	34	18	33
35	51	54	70	64	62	41	47	52	45	54	52	51
15	30	38	47	33	38	36	41	45	40	40	37	41
46	39	46	23	38	18	16	41	36	63	44	51	43
62	68	74	69	89	71	61	48	38	34	51	49	60
48	71	80	82	77	75	47	54	35	31	51	38	55
71	60	55	61	56	71	70	49	41	37	26	28	59
15	38	65	74	94	101	86	84	79	71	47	43	62
558	682	746	737	739	649	551	592	536	520	533	472	584
46	57	62	61	62	54	46	49	45	43	44	39	49
83	89	84	75	69	73	73	87	39	43	40	51	65
79	106	70	63	77	86	77	69	71	61	59	61	68
12	18	11	23	26	20	36	29	10	21	17	30	23
52	75	85	83	80	45	50	47	29	27	20	16	42
37	46	48	31	51	65	32	34	69	30	44	46	42
52	50	65	61	60	70	50	63	63	55	56	53	53
77	91	108	92	79	64	75	83	70	62	52	43	60
71	86	90	108	81	73	68	58	59	33	32	30	54
80	77	83	84	66	90	80	69	59	72	73	70	78
69	83	86	69	81	84	71	44	75	84	76	46	71
612	721	730	689	670	670	612	583	544	488	469	446	556
61	72	73	69	67	67	61	58	54	49	47	45	56
65	110	101	87	102	103	89	78	55	100	105	90	86
53	91	70	61	93	79	49	49	62	66	67	60	62
49	61	56	55	40	30	49	47	55	40	26	57	52
37	59	47	40	28	31	20	50	38	29	22	11	38
72	109	86	69	83	39	26	33	27	26	24	32	44
55	46	64	74	76	80	82	54	79	47	42	32	55
85	106	65	54	81	86	72	67	49	60	71	57	66
416	582	489	440	503	448	387	378	365	368	357	339	403
59	83	70	63	72	64	55	54	52	53	51	48	58

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N. Y.*

JULY, 1886, TO SEPTEMBER, 1887, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

JULY, 1886.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1	115	80	80	70	86	N. lt., clear.
2	65	70	53	82	68	SW. lt., fair.
3	40	60	80	108	72	Do.
4	75	112	102	90	95	NW. lt., clear.
5	85	46	30	43	51	Do.
6	88	70	72	85	79	NW. lt., fair.
7	— 16	21	30	25	15	NW. fr., fair, threatening, t. s.
8	65	80	50	75	68	NW. br., clear.
9	145	95	82	67	97	S. lt., fair.
10	122	25	65	94	76	NW. lt., fair.
11	65	83	75	68	73	NW. br., fair.
12	135	43	63	62	76	NW. lt., clear.
13	34	35	50	50	42	S. br., threatening.
14	57	—220	—198	45	—79	SE. br., cloudy, rain.
15	76	230	60	63	107	Var. fr., cloudy.
16	110	114	30	62	79	SW. gen., cloudy.
17	— 3	— 49	30	27	1	NW. lt., cloudy, rain, t. s.
18	95	77	—480	— (*)	—103	SW. fr., cloudy, rain, t. s.
19	10	(†)	13	65	29	Cloudy.
20	24	— 3	48	92	40	W. lt., cloudy.
21	58	73	84	106	80	Cloudy.
22	90	118	152	180	135	Clear.
23	87	95	60	102	86	Do.
24	20	180	135	121	114	Do.
25	85	118	88	72	91	S. fr., fair.
26	133	148	146	168	149	SW. lt., cloudy, rain.
27	65	90	120	133	102	W. fr., cloudy.
28	— 12	75	85	70	54	Fair.
29	85	86	120	131	105	Cloudy, rain.
30	75	85	72	126	89	Cloudy.
31	— 20	35	98	155	67	W. fr., fair.
Sums	2,053	2,072	1,495	2,637	2,044	
Means	66	69	48	88	66	NW. lt., cloudy.

AUGUST, 1886.

1	53	117	115	133	104	S. br., fair, t. s.
2	95	110	80	95	95	NW. br., fair.
3	0	68	65	95	57	NW. high, cloudy.
4	80	75	60	75	72	W. lt., fair.
5	3	— 12	28	98	29	W. lt., cloudy, rain.
6	75	90	130	120	104	Fair.
7	140	— 14	141	107	94	Cloudy, rain.
8	75	45	45	85	62	Clear.
9	45	110	102	118	94	SW. fr., clear.
10	65	85	120	115	96	S. fr., fair.
11	105	45	125	88	91	SW. fr., cloudy, rain.
12	160	157	177	135	157	NW. lt., fair.
13	70	70	113	158	103	SE. fr., fair, t. s.
14	3	120	115	160	100	NW. br., cloudy.
15	70	70	100	145	96	NW. lt., clear.
16	12	— 41	—220	1,101	213	S. br., cloudy, rain.
17	70	55	60	— 45	35	W. fr., cloudy.
18	100	110	105	125	110	Clear.
19	160	80	80	88	102	W. lt., clear.
20	120	105	105	100	108	SW. lt., fair.
21	50	95	100	135	95	SW. br., fair.
22	97	100	110	118	106	SW. fr., clear.
23	105	108	105	100	104	SW. fr., cloudy.
24	110	90	108	100	102	SW. fr., fair.
25	110	190	109	115	131	NW. fr., fair.
26	80	78	85	125	92	N. lt., clear.
27	95	85	102	145	107	Clear.
28	95	100	95	90	95	Do.
29	115	75	71	105	92	SW. fr., fair.
30	39	— 10	90	255	94	SW. br., cloudy, rain.
31	180	195	190	125	175	NW. fr., hazy.
Sums	2,577	2,551	2,811	4,509	3,115	
Means	83	82	91	145	100.5	SW. fr., fair.

† Omitted.

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N. Y.*—Cont'd.

JULY, 1886, TO SEPTEMBER, 1887, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

SEPTEMBER, 1886.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1	70	80	105	110	91	NW. fr., fair.
2	83	92	130	115	105	
3	120	120	150	150	135	W. fr., fair.
4	125	80	138	152	124	SW. fr., cloudy.
5	100	105	115	130	112	W. fr., cloudy.
6	107	125	110	118	115	W. fr., hazy.
7	90	115	105	85	99	Do.
8	98	120	130	118	116	SW. fr., clear.
9	57	60	76	60	63	SW. fr., fair.
10	110	120	77	100	102	Do.
11	84	73	55	70	70	NW. fr., clear.
12	30	— 76	333	— 20	67	SE. lt., cloudy, rain.
13	250	110	90	77	132	NW. br., fair.
14	20	99	128	78	81	SW. br., rain, cloudy.
15	52	85	87	85	77	SE. fr., cloudy.
16	—235	45	58	83	—12	S. fr., rain, cloudy.
17	55	41	35	75	52	SW. br., fair.
18	40	31	45	80	49	Clear.
19	155	220	42	167	146	SW. high, rain, cloudy.
20	65	95	85	75	80	NW. fr., fair.
21	42	71	75	75	66	Do.
22	120	75	85	123	101	NW. lt., cloudy.
23	125	130	101	147	126	NE. lt., fair.
24	175	122	120	150	142	Cloudy.
25	103	90	152	50	99	SW. fr., cloudy.
26	— 25	70	70	65	45	SW. br., rain, cloudy.
27	25	140	160	92	104	Cloudy.
28	52	90	55	25	56	Var. lt., cloudy.
29	145	35	103	95	94	NW. fr., fair.
30	120	110	130	140	125	W. br., clear.
Sums	2,358	2,673	3,145	2,870	2,762	
Mean	79	89	105	96	92.1	SW. fr., cloudy.

OCTOBER, 1886.

1	50	55	42	47	48	NW. br., cloudy.
2	58	65	85	105	78	Do.
3	105	95	88	100	97	N. lt., clear.
4	105	95	150	140	122	SW. fr., cloudy.
5	— 10	35	50	110	46	NW. lt., hazy, cloudy.
6	90	97	131	155	118	W. lt., haze.
7	195	235	200	125	189	Hazy, clear.
8	80	165	160	133	134	W. lt., hazy, clear.
9	142	92	109	150	123	W. fr., hazy, clear.
10	198	175	145	130	162	W. lt., hazy, clear.
11	85	75	60	65	71	SW. fr., hazy, clear.
12	82	88	103	290	141	SW. lt., cloudy, rain.
13	15	110	35	98	64	Cloudy.
14	— 39	— 59	— 95	13	—45	SW. high, cloudy, rain.
15	67	90	20	70	62	NW. br., cloudy, rain.
16	85	110	65	65	81	NW. br., cloudy.
17	130	95	—712	— 72	—140	SW. fr., fair, snow, rain, sleet.
18	85	65	200	210	140	NW. lt., cloudy.
19	230	135	140	175	170	W. fr., cloudy.
20	150	220	195	220	196	W. br., clear, hazy, cloudy.
21	45	95	60	100	75	NW. br., fair.
22	150	160	165	175	162	NW. lt., clear.
23	180	370	370	260	295	W. fr., clear.
24	105	90	50	60	76	S. br., clear, cloudy.
25	110	235	195	130	168	SW. fr., cloudy.
26	83	74	69	—107	30	N. fr., cloudy.
27	34	— 1	26	— 6	13	Rain, fog, cloudy.
28	280	117	182	131	178	Rain, fog.
29	— 31	4	— 43	—494	—141	Cloudy, rain.
30	190	25	70	215	125	N. fr., cloudy, rain.
31	40	70	125	120	89	Do.
Sums	3,089	3,277	2,440	2,913	2,927	
Mean	100	106	79	94	94.4	NW. fr., cloudy.

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N. Y.*—Cont'd.

JULY, 1886, TO SEPTEMBER, 1887, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

NOVEMBER, 1886.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1	263	253	210	163	222	Clear.
2	298	195	130	148	193	Fair.
3	142	140	99	110	123	S. fr., fair, hazy.
4	190	105	155	120	142	WNW. br., fair.
5	113	146	162	141	140	SW. high, cloudy.
6	— 81	18	— 15	500	106	NNW. lt., cloudy, rain, snow.
7	23	88	98	160	92	NNW. br., cloudy, snow.
8	105	52	55	60	68	NW. br., cloudy, snow.
9	105	170	200	210	171	SW. fr., cloudy.
10	50	22	174	.....	82	SE. fr., cloudy.
11	39	103	39	— 30	38	SW. lt., cloudy, rain.
12	15	— 156	—115	280	6	Cloudy, snow.
13	1,100	1,100	.....	1,800	1,333	N. fr., snow.
14	— 203	— 310	—340	6	— 212	NW. fr., clear.
15	135	185	85	—120	71	W. fr., fair.
16	220	260	240	280	250	Clear, cloudy.
17	— 590	— 740	—270	—480	— 520	SE. br., rain.
18	— 6	90	—215	50	— 20	W. br., rain, fair.
19	50	180	267	187	171	SW. high, cloudy, snow.
20	166	225	240	60	173	SW. fr., cloudy.
21	132	120	125	— 25	88	W. fr., clear.
22	145	212	180	170	177	S. lt., fair.
23	— 6	17	125	84	55	W. br., rain, cloudy.
24	0	— 180	— 15	15	— 45	NWW. fr., cloudy.
25	— 31	— 712	450	—690	— 246	SE. fr., snow.
26	115	110	170	215	152	W. br., clear.
27	148	185	205	178	179	W. br., fair.
28	68	108	125	48	87	S. fr., cloudy.
29	25	125	140	65	89	SW. br., cloudy.
30	98	109	— 31	490	166	NW. lt., snow.
Sums	2,828	2,220	2,673	4,195	3,331	
Means	94	74	92	145	111	W. fr., cloudy.

DECEMBER, 1886.

1	110	175	210	195	172	SW. lt., cloudy.
2	— 165	— 495	134	500	— 6	W. br., cloudy, snow.
3	522	— 183	— 388	—301	— 88	NW. br., snow, fair, cloudy.
4	1,500	330	130	—160	450	NNW. fr., snow, fair, cloudy.
5	— 150	— 5	— 527	—342	— 256	Cloudy, snow.
6	— 185	127	255	387	146	NW. lt., snow, clear.
7	— 250	— 130	— 16	— 85	— 120	Fog, cloudy, snow.
8	255	130	110	96	148	SE. lt., fair, cloudy.
9	— 16	60	2	136	46	Cloudy, fair.
10	290	35	270	225	205	SE. fr., clear.
11	65	275	130	110	145	Var. lt., clear.
12	230	285	240	120	219	Cloudy, fair.
13	— 50	— 110	68	52	— 10	S. fr., rain, cloudy.
14	— 302	— 80	22	75	— 71	NW. br., cloudy.
15	2,050	1,700	350	700	1,200	NW. br., snow.
16	21	— 250	75	— 75	— 57	NNW. fr., cloudy, snow.
17	172	170	263	268	218	WSW. fr., cloudy.
18	— 180	— 80	— 625	— 65	— 238	SE. fr., cloudy, rain.
19	— 170	— 50	25	—125	— 80	N. lt., snow, cloudy.
20	30	100	175	200	126	Cloudy.
21	155	190	245	200	198	W. fr., fair, clear.
22	205	75	250	190	170	S. lt., snow.
23	280	180	172	—125	127	SE. br., cloudy.
24	180	250	250	75	189	SES. br., cloudy.
25	450	— 250	— 355	—625	— 195	NW. br., snow, cloudy.
26	210	1,350	1,520	100	795	SE. br., snow, cloudy.
27	1,300	550	100	—280	418	WNW. br., cloudy, snow.
28	— 10	50	150	150	85	NW. lt., fair.
29	950	385	66	— 40	340	NW. br., snow.
30	— 55	237	305	245	183	Snow.
31	410	215	57	187	217	S. fr., snow, cloudy.
Sums	7,852	5,196	3,663	1,988	4,676	
Means	253	168	118	64	151	NW. br., snow, cloudy.

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N. Y.*—Cont'd.

JULY, 1886, TO SEPTEMBER, 1887, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

JANUARY, 1887.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1	1,795	450	830	65	785	NW. fr., snow.
2	1,345	1,545	1.675	225	1,198	NW. br., cloudy.
3	220	70	120	295	176	NW. lt., fair.
4	582	220	70	310	296	NW. fr., fair.
5	317	320	300	307	311	S. lt., snow, cloudy.
6	127	132	67	265	148	Cloudy.
7	120	237	130	1,790	569	NW. lt., clear, snow.
8	182	297	22	417	230	NW. lt., clear.
9	(†)	(†)	(†)	(†)	(†)	
10	— 130	40	90	92	23	NW. br., snow, fair.
11	205	315	265	250	259	SE. fr., clear.
12	90	65	122	22	75	SESW. br., cloudy, snow.
13	2	— 32	— 2	— 10	— 10	S. lt., cloudy, snow.
14	— 20	(†)	20	12	4	Rain, cloudy.
15	— 7	— 35	— 17	— 20	— 20	NW. fr., snow.
16	107	67	45	95	78	SE. lt., snow, cloudy.
17	— 10	85	— 18	— 8	12	S. fr., cloudy, rain.
18	1,600	157	900	735	848	NW. br., snow, cloudy.
19	— 40	— 52	47	117	18	S. br., cloudy.
20	67	— 27	— 20	— 27	— 2	Do.
21	20	5	— 12	— 112	— 25	SW. fr., cloudy, snow.
22	110	— 10	10	227	84	SE. br., fair.
23	(†)	(†)	(†)	(†)	(†)	
24	— 55	— 52	— 47	— 562	— 179	W. br., rain, snow, cloudy.
25	257	12	55	150	118	SE. br., cloudy, fair.
26	430	55	17	1,750	563	N. fr., snow.
27	171	100	90	42	101	S. lt., clear.
28	— 425	— 10	45	— 7	— 99	S. br., cloudy.
29	— 5	60	165	167	97	Snow, cloudy.
30	15	110	45	117	72	W. fr., snow, cloudy.
31	— 680	— 352	— 165	— 77	— 318	NW. lt., cloudy, snow.
Sums	6,390	3,772	4,849	6,627	5,412	
Means	220	135	167	229	187	NW. br., snow, cloudy.

FEBRUARY, 1887.

1	560	50	55	135	200	N. lt., snow, cloudy.
2	1,300	— 150	— 600	— 420	32	ES. fr., snow, cloudy.
3	— 100	— 325	— 78	100	—101	S. lt., rain, cloudy.
4	52	363	— 200	— 75	35	NWN. fr., snow, cloudy.
5	138	290	232	270	232	Fair.
6	63	23	82	112	70	Cloudy, rain.
7	— 177	—1,215	— 308	— 205	—476	Cloudy, snow, rain.
8	60	— 352	52	37	— 51	S. br., cloudy.
9	— 352	— 145	— 247	— 275	—255	NW. br., fair.
10	150	280	200	90	180	S. fr., clear, cloudy.
11	— 85	— 535	— 300	24	—224	NW. lt., fog, rain, cloudy.
12	— 480	— 572	— 185	175	—266	NW. fr., cloudy, snow.
13	55	— 231	413	— 438	— 50	NW. fr., fair.
14	— 33	— 80	15	45	— 13	S. br., clear.
15	— 48	7	— 3	19	— 6	S. lt., cloudy.
16	64	30	37	45	44	Cloudy.
17	— 127	— 67	— 192	45	— 85	NW. lt., cloudy, clear.
18	1,312	663	93	141	552	S. high, snow, cloudy.
19	127	— 137	— 45	— 12	— 17	Cloudy, snow.
20	30	— 41	— 120	— 168	— 75	N. lt., cloudy.
21	161	— 335	— 242	— 300	—179	Cloudy.
22	15	— 85	— 142	— 100	— 78	Var. lt., snow, cloudy.
23	75	183	97	60	104	S. fr., cloudy.
24	0	132	77	105	78	NW. high, cloudy, snow.
25	105	— 37	— 48	— 273	— 63	NW. lt., cloudy, clear.
26	450	627	1,035	557	667	S. high, snow.
27	65	222	(†)	(†)	144	W. fr., cloudy, snow.
28	1,500	149	— 75	60	408	NW. br., fair.
Sums	4,880	—1,288	— 397	— 246	807	
Means	174	— 46	— 15	— 9	29	NW. lt., cloudy, snow.

† Omitted.

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means Ithaca, N. Y.*—Cont'd.

JULY, 1886, TO SEPTEMBER, 1887, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

MARCH, 1887.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1	22	— 35	— 130	0	— 36	SW. fr., cloudy.
2	92	90	87	95	91	S. fr., hazy.
3	120	— 102	— 50	— 150	— 46	Cloudy.
4	17	37	— 40	30	11	Fair.
5	150	17	— 60	250	89	SSE. fr., cloudy, snow.
6	— 830	—1,250	— 537	— 20	— 659	S. fr., rain, snow, cloudy.
7	147	207	110	30	124	Cloudy.
8	— 20	— 42	— 10	— 365	— 109	N. lt., clear.
9	140	62	45	0	62	S. br., clear.
10	— 385	— 77	— 207	— 150	— 205	NW. fr., cloudy.
11	287	— 300	62	(†)	16	NW. br., snow.
12	55	55	45	20	44	NW. fr., clear.
13	225	305	35	20	146	S. lt., fair, cloudy.
14	— 150	— 155	— 230	1,075	135	NW. fr., br., sleet, cloudy, snow.
15	650	265	80	180	294	NW. fr., snow.
16	15	— 150	65	130	15	NW. fr., cloudy, snow.
17	1,000	500	170	130	450	Do.
18	225	210	220	400	264	Do.
19	50	— 65	10	— 95	— 25	NW. fr., cloudy.
20	80	185	85	65	104	Var. lt., cloudy.
21	55	165	55	150	106	S. lt., cloudy.
22	100	500	1,500	1,300	850	N. br., snow.
23	— 225	— 45	25	50	— 49	W. br., cloudy, fair.
24	110	(†)	105	160	125	E. br., cloudy, hazy.
25	(†)	(†)	— 35	— 140	— 88	NW. br., fair.
26	0	85	65	80	57	N. fr., snow, fair.
27	70	95	20	80	66	S. fr., cloudy.
28	— 280	— 30	— 155	— 35	— 125	W. lt., rain, cloudy.
29	(*)	2,900	2,300	1,260	2,153	W. fr., snow.
30	212	196	115	97	155	NW. br., fair.
31	290	270	285	200	261	E. lt., clear.
Sums	2,222	3,893	4,030	4,847	4,276	
Mean	77	134	130	162	138	NW. fr., cloudy.

† Omitted.

APRIL, 1887.

1	—157	35	—137	127	— 33	Fair.
2	127	177	43	67	104	N. lt., clear.
3	170	92	123	112	124	Fair.
4	7	52	23	—322	— 60	S. lt., cloudy, rain.
5	15	17	984	75	273	NW. br., cloudy, snow.
6	—106	—119	—124	—225	—144	NW. lt., fair.
7	72	—310	—245	—200	—171	Do.
8	217	250	200	140	202	Clear.
9	167	167	147	15	124	SW. lt., hazy.
10	147	105	27	0	70	Hazy.
11	—187	—145	— 42	115	— 64	NW. lt., hazy, rain.
12	—350	—205	—167	—262	—246	Cloudy.
13	— 8	32	34	81	35	NE. lt., cloudy, rain.
14	25	95	81	65	66	NE. br., cloudy.
15	11	(*)	—122	9	— 34	E. br., rain.
16	—155	—162	—372	—265	—238	W. br., rain.
17	—293	— 70	—100	—322	—196	W. lt., fair.
18	732	450	175	30	347	SE. lt., snow.
19	—213	—145	0	—105	—116	Fair.
20	157	217	180	95	162	SW. lt., clear.
21	87	115	106	72	95	W. fr., clear.
22	167	162	140	122	148	W. fr., hazy, rain.
23	85	85	57	38	66	SW. br., cloudy, rain.
24	— 72	— 60	—240	— 57	—107	NW. lt., fair.
25	126	104	90	106	106	SW. lt., fair.
26	— 88	—128	150	41	— 6	W. lt., cloudy.
27	124	—121	—237	— 52	— 72	Cloudy.
28	135	120	65	11	83	SW. br., rain.
29	— 16	—220	—157	—203	—149	W. lt., rain.
30	— 66	22	— 50	275	45	NW. br., cloudy.
Sums	860	612	632	—417	414	
Mean	29	21	21	— 14	14	WNW. lt., cloudy, rain.

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N. Y.*—Cont'd.

JULY, 1886, TO SEPTEMBER, 1887, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

MAY, 1887.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1	—220	247	—137	— 77	— 47	NW. lt., fair.
2	121	105	111	99	109	Var. lt., fair.
3	143	110	— 11	— 27	54	SW. lt., hazy.
4	132	—187	—160	—160	— 94	W. lt., fair.
5	11	—148	—110	—203	—112	W. lt., cloudy.
6	110	110	99	105	106	W. fr., cloudy.
7	148	137	105	88	120	NW. br., cloudy, rain.
8	137	88	99	93	104	E. lt., cloudy.
9	—132	71	137	—105	— 7	Cloudy.
10	—181	— 77	— 33	0	— 73	Do.
11	—132	82	93	0	11	NW. fr., clear.
12	— 55	— 77	— 11	187	11	Hazy.
13	99	143	115	110	117	NW. lt., clear.
14	—242	27	— 11	— 55	— 70	W. lt., clear.
15	— 93	50	— 6	— 11	— 15	Clear.
16	71	5	55	115	62	N. lt., fair.
17	0	— 55	0	77	6	Hazy.
18	—160	— 55	55	0	— 40	Cloudy, rain.
19	44	— 77	5	3	— 6	Hazy.
20	66	105	121	77	92	Do.
21	— 38	16	27	5	2	Clear.
22	44	44	44	55	47	SW. lt., hazy.
23	137	121	126	(†)	128	S. fr., fair.
24	— 33	44	— 66	88	8	SW. br., cloudy, rain.
25	137	33	88	11	67	NW. fr., rain.
26	27	22	27	55	33	NE. lt , rain, cloudy.
27	5	55	— 44	71	22	W. lt., rain.
28	(*)	— 33	— 16	66	6	NW. fr., rain, cloudy.
29	— 16	— 66	— 16	— 25	— 31	SW. lt., clear.
30	192	105	140	— 77	90	S. lt., clear.
31	99	154	110	110	118	SW. lt., cloudy.
Sums	421	1,099	936	675	818	
Means	14	35	30	22	26	NW. lt., cloudy.

† Omitted.

JUNE, 1887.

1	203	88	14	139	111	W. br., cloudy, rain.
2	38	—181	258	95	52	S. lt., rain, cloudy.
3	— 44	11	11	22	0	Cloudy.
4	66	2	82	13	41	W. fr., clear.
5	137	84	71	126	104	S. lt., cloudy.
6	154	137	57	137	121	SW. lt., rain.
7	— 11	46	33	44	28	Cloudy.
8	115	22	19	38	48	W. lt., cloudy.
9	38	— 3	110	104	62	NW. fr., cloudy, rain.
10	— 60	— 22	33	55	2	N. lt., cloudy.
11	99	82	101	88	92	SENW. fr., fair.
12	143	44	47	47	70	NW. lt., clear.
13	27	68	71	65	58	N. lt., fair.
14	115	148	148	11	106	NW. fr., clear.
15	44	115	126	93	94	SW. fr., fair.
16	61	55	38	44	50	SW. fr., cloudy.
17	19	88	— 22	28	28	NW. lt., cloudy, rain.
18	181	71	27	110	97	NE. lt., cloudy.
19	99	44	82	93	80	NW. fr., cloudy, rain.
20	146	132	93	77	112	NW. lt., fair.
21	82	57	71	66	69	S. fr., cloudy.
22	.....	71	159	116	115	S. lt., rain, t. s.
23	115	137	123	93	117	S. fr., fair.
24	17	44	— 44	13	8	N. lt., cloudy, rain.
25	27	66	11	88	48	NW. lt., fair.
26	22	88	82	88	70	NW. fr., fair.
27	114	93	167	148	130	NW. lt., cloudy.
28	183	88	91	121	121	NW. fr., fair,
29	160	82	82	99	106	NW. fr., clear.
30	81	88	66	88	84	NW. lt., clear.
Sums	2,371	1,845	2,207	2,349	2,221	
Means	82	62	74	78	74	NW. lt., cloudy.

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N. Y.*—Cont'd.

JULY, 1886, TO SEPTEMBER, 1887, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

JULY, 1887.

Day of month.	9 a.m.	11 a.m.	1 p.m.	3 p.m.	Means.	Remarks.
1	110	104	99	104	104	SW. fr., fair.
2	104	104	132	143	121	SW. fr., fair, rain.
3	66	82	77	79	76	SE. lt., clear.
4	71	77	60	82	72	SW. br., fair.
5	77	6	—115	— 35	— 17	SE. br., cloudy, rain.
6	15	30	50	2,100	549	SW. fr., rain.
7	45	60	60	65	58	NW. fr., clear.
8	50	75	85	(†)	70	NW. lt., cloudy.
9	(†)	(†)	(†)	(†)	(†)	
10	(†)	(†)	(†)	(†)	(†)	
11	(†)	(†)	(†)	(†)	(†)	
12	(†)	(†)	(†)	(†)	(†)	
13	125	125	112	112	118	NW. lt., fair.
14	72	80	110	120	95	NW. fr., cloudy.
15	115	125	155	115	127	W. lt., rain.
16	150	95	— 65	145	81	W. br., fair, rain.
17	140	125	90	100	114	W. lt., rain, fair.
18	210	65	110	80	116	NW. fr., cloudy, rain.
19	95	80	75	110	90	NW. fr., fair.
20	190	105	95	25	104	W. fr., fair.
21	120	70	10	125	81	SE. fr., cloudy, rain.
22	85	— (*)	50	75	70	W. fr., cloudy, rain.
23	60	60	45	80	61	NW. fr., cloudy.
24	30	30	55	70	46	Fair.
25	215	— (*)	— (*)	— (*)	215	Rain.
26	55	20	60	10	36	NW. fr., cloudy.
27	75	70	85	80	77	NW. lt., clear.
28	125	90	80	100	99	W. lt., clear.
29	25	50	80	100	64	NW. fr., cloudy, rain.
30	100	80	100	155	109	SW. fr., fair.
31	85	70	85	90	82	W. lt., clear.
Sums	2,610	1,878	1,780	4,230	2,818	
Means	97	75	68	169	104	NW. fr., rain, cloudy.

†Omitted.

AUGUST, 1887.

1	50	25	55	85	54	Fair.
2	80	55	42	65	60	NW. lt., cloudy.
3	— 10	20	60	65	34	NW. fr., cloudy.
4	40	60	75	65	60	S. fr., cloudy.
5	85	90	40	50	66	SW. fr., cloudy, rain.
6	95	55	80	105	84	NW. fr., cloudy, rain.
7	70	70	65	60	66	NW. fr., clear.
8	125	75	115	110	106	S. lt., clear.
9	80	80	80	95	84	SW. fr., fair.
10	65	50	40	150	76	S. lt., cloudy, rain.
11	35	80	— (*)	5	40	Cloudy, rain.
12	55	115	75	110	89	NW. fr., clear.
13	65	105	110	105	96	NW. lt., clear.
14	125	85	85	55	87	Fair.
15	60	50	80	90	70	SW. fr., cloudy.
16	35	40	70	65	52	NW. fr., cloudy, rain.
17	85	105	85	125	100	W. fr., cloudy, rain.
18	140	75	25	80	80	NW. fr., cloudy, rain.
19	45	75	65	70	64	NW. fr., cloudy.
20	— 30	70	125	135	75	NW. fr., fair.
21	75	85	155	120	109	NW. lt., hazy, rain.
22	0	10	190	135	84	NW. lt., cloudy, rain.
23	155	140	115	105	129	NW. br., cloudy, rain.
24	135	135	80	90	110	NW. fr., cloudy, rain.
25	135	100	150	125	127	NW. gale, fair.
26	135	115	135	150	134	Do.
27	— 15	90	120	120	79	NW. br., fair.
28	35	30	35	50	37	NW. fr., fair.
29	— 25	100	88	105	67	NW. fr., clear.
30	105	150	85	60	100	Do.
31	145	100	105	85	109	Clear.
Sums	2,175	2,435	2,630	2,835	2,528	
Means	70	79	88	91	82	NW. fr., cloudy, rain.

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N. Y.*—Cont'd.

JULY, 1886, TO SEPTEMBER, 1887, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

SEPTEMBER, 1887.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1	120	(†)	(†)	(†)	120	Clear.
2	30	110	80	150	92	W. lt., cloudy, rain.
3	70	85	85	100	85	NW. fr., cloudy.
4	60	45	60	65	57	NW. lt., clear.
5	100	60	90	90	85	W. fr., clear.
6	110	35	45	.....	63	S. fr., cloudy.
7	80	210	—2,250	80	—470	SW. br., cloudy, rain.
8	70	70	(†)	80	73	NW. fr., fair.
9	115	110	115	90	107	SW. br., cloudy.
10	50	120	60	85	79	NW. fr., cloudy.
11	135	110	95	95	109	E. lt., cloudy.
12	85	105	0	— 35	39	SW. lt., cloudy.
13	— 35	70	120	40	49	S. fr., rain, cloudy.
14	75	90	70	85	80	NW. fr., fair.
15	50	115	105	85	89	Cloudy, rain.
16	115	145	70	85	104	N. lt., cloudy, rain.
17	30	(†)	(†)	(†)	30	N. lt., clear.
18	(†)	(†)	(†)	(†)	(†)	
19	50	60	70	100	70	N. fr., clear.
20	60	190	190	185	156	NW. lt., clear.
21	190	150	150	.....	163	S. lt., hazy.
22	.....	.....	.....	.....	.....	
23	.....	.....	.....	.....	.....	
24	.....	.....	.....	.....	.....	
25	.....	.....	.....	.....	.....	
26	.....	.....	.....	.....	.....	
27	.....	.....	.....	.....	.....	
28	.....	.....	.....	.....	.....	
29	.....	.....	.....	.....	.....	
30	.....	.....	.....	.....	.....	
Sums	1,560	1,900	— 845	1,380	1,180	
Means	78	106	— 50	86	59	NW. lt., cloudy.

† Omitted.

SUMMARY.

July, 1886	66	69	48	88	68	NW. lt., cloudy.
August, 1886	83	82	91	145	100	SW. fr., fair.
September, 1886	79	89	105	96	92	SW. fr., cloudy.
October, 1886	100	106	79	94	95	NW. fr., cloudy.
November, 1886	94	74	92	145	101	W. fr., cloudy.
December, 1886	253	168	118	64	151	NW. br., cloudy, snow.
January, 1887	220	135	167	229	188	NW. br., snow, cloudy.
February, 1887	174	— 46	— 15	— 9	26	NW. lt., snow, cloudy.
March, 1887	77	134	130	162	126	NW. fr., cloudy.
April, 1887	29	21	21	— 14	14	NW. lt., cloudy, rain.
May, 1887	14	35	30	22	25	NW. lt., cloudy.
June, 1887	82	62	74	78	74	Do.
July, 1887	97	75	68	169	102	NW. fr., rain, cloudy.
August, 1887	70	79	88	91	82	NW. fr., cloudy, rain.
September, 1887	78	106	— 50	86	55	NW. lt., cloudy.
Sums	1,516	1,189	1,046	1,446	1,299	
Means	101	79	70	96	87	

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N. Y.*—Cont'd.

OCTOBER, 1887, TO AUGUST, 1888, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

OCTOBER, 1887.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1							
2							
3							
4							
5	292	143	— 68	55	40	92	W. fr., lt. rain.
6	403	278	(†)	(†)	242	303	W. lt., cloudy.
7	540	210	210	275	281	303	W. lt., fair.
8	375	342	243	235	270	293	SW. lt., fair.
9							
10							
11							
12							
13							
14	364	210	167	249	268	252	NW. br., fair.
15	546	400	362	308	398	403	NW. lt., clear.
16	382	236	150	164	173	221	SW. fr., fair.
17	418	450	216	199	152	287	S. fr., cloudy.
18	150	132	105	120	250	151	SW. br., cloudy.
19	636	108	22	161	180	221	NW. fr., fair.
20	—(*)	—736	100	201	154	— 70	S. br., cloudy, fog.
21	—(*)	125	150	150	318	186	SW. br., lt. rain.
22	80	80	— 45	48	105	54	W. br., lt. snow.
23	— 72	115	135	165	198	137	W. br., cloudy.
24	499	364	264	88	16	246	NW. br., cloudy.
25	722	644	510	425	505	561	W. fr., cloudy.
26	1,197	950	725	766	680	563	W. lt., fair.
27	72	110	55	197	121	82	SE. fr., cloudy.
28	368	385	204	214	214	277	NW. gen., fair.
29	270	258	229	236	185	236	S. fr., cloudy.
30	88	121	251	302	348	222	W. fr., cloudy, snow.
31	455	368	330	317	367	367	SW. gen., clear.
Sums	6,225	5,293	4,315	4,875	5,365	5,392	
Means	311	241	206	232	244	247	W. fr., cloudy.

NOVEMBER, 1887.

1	264	430	312	249	304	312	NW. br., clear.
2	434	435	300	315	343	365	N. gen., clear.
3	330	330	355	353	370	348	S. fr., fair.
4	311	125	— 76	27	90	95	NW. br., cloudy.
5	180	513	210	300	774	395	NW. high, fair.
6	331	450	205	260	410	371	S. lt., clear.
7	425	546	426	244	299	388	S. br., hazy.
8	150	55	185	300	336	205	NW. br., cloudy.
9	391	443	335	340	330	368	E. gen., clear.
10	266	—269	21	0	43	14	S. high, rain.
11	1,321	2,390	628	2,063	1,588	1,598	NW. high, snow.
12	— 53	200	134	155	195	126	NW. high, cloudy.
13	256	310	140	218	361	257	NW. lt., fair.
14	269	399	246	242	76	246	SE. fr., cloudy.
15	76	91	48	63	20	60	NW. br., cloudy, rain.
16	— 33	76	100	166	113	84	NW. fr., cloudy.
17	70	373	180	195	180	200	W. high, fair.
18	506	570	219	286	177	352	W. br., clear.
19	—135	—336	40	591	329	98	SE. br., snow, sleet.
20	485	415	149	198	206	291	SW. br., cloudy.
21	104	130	127	255	264	176	Do.
22	134	340	481	376	603	387	E. gen., hazy.
23	129	29	134	201	389	176	S. gen., hazy.
24	105	62	201	196	200	154	NW. gen., snow, rain, sleet.
25	294	—228	91	200	38	61	S. gen., cloudy.
26	348	615	504	266	164	379	Do.
27	22	—148	—272	176	117	— 21	S. fr., clear.
28	—576	—139	—550	— 95	—130	—298	NW. fr., fair, sleet.
29	151	—482	—1,073	157	—455	—340	NW. fr., clear.
30	530	132	349	577	150	428	N. br., cloudy, snow.
Sums	6,985	9,461	6,196	8,935	8,469	7,934	
Means	233	262	141	295	263	242	NW. br., cloudy.

†Omitted.

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N. Y.*—Cont'd.

OCTOBER, 1887, TO AUGUST, 1888, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

DECEMBER, 1887.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1	1,053	1,131	1,195	537	874	958	E. lt., clear.
2	—117	101	—130	213	139	41	S. fr., cloudy.
3	126	599	652	585	537	500	S. gen., cloudy.
4	—120	— 30	—210	— 98	— 63	—104	S. fr., cloudy.
5	5	—322	—139	—218	—200	—175	W. br., cloudy, snow.
6	590	380	149	256	440	363	Var. lt., clear.
7	910	734	659	450	300	611	SE. fr., cloudy.
8	350	185	352	274	550	342	N. fr., cloudy.
9	940	830	784	740	820	823	E. br., fair.
10	—547	821	1,133	567	484	492	SE. br., rain.
11	714	630	600	473	211	526	SW. lt., cloudy.
12	—433	51	100	175	264	31	NW. br., snow.
13	300	560	800	680	791	626	Var. lt , clear.
14	760	880	970	780	640	806	SE. fr., fair.
15	610	410	245	122	58	289	SW. lt., cloudy.
16	— 92	—412	—180	—114	— 50	—170	NW. br., cloudy.
17	1,050	1,176	987	950	846	1,002	SE. fr., cloudy.
18	1,937	1,929	1,938	1,970	1,792	1,913	NW. br., snow.
19	141	127	201	377	156	200	NW. fr., cloudy.
20	780	1,012	1,700	1,114	2,002	1,322	S. lt., cloudy.
21	—109	—295	—360	—413	—190	—273	NW. fr., threatening.
22	630	425	—238	42	426	257	SW. br., cloudy, snow, fair.
23	407	392	705	375	485	473	S. lt., snow, fair.
24	817	785	896	575	490	713	SE. fr., cloudy.
25	305	320	335	235	303	300	Var. lt., cloudy.
26	447	755	798	1,075	1,090	833	SE. fr., cloudy, snow.
27	450	826	912	919	720	765	SE. fr., clear.
28	637	1,101	—238	421	62	397	NW. br., snow, cloudy.
29	(*)	(*)	(*)	(*)	(*)	(*)	NW. gale, snow.
30	(*)	2,330	(*)	318	300	983	NW. high, snow, fair.
31	585	3,040	120	(*)	907	1,163	SE. br., snow.
Sums	13,126	20,471	14,736	13,378	15,184	16,007	
Means	453	682	508	461	506	534	NWSE. fr., cloudy.

JANUARY, 1888.

1	—(*)	150	— 5	—198	—500	—138	S. br., threatening.
2	13	280	515	550	300	332	NW. fr., snow, cloudy.
3	—310	—605	—1,013	176	— 18	—354	NW. fr., snow.
4	550	600	500	92	695	487	SE. fr., snow, cloudy.
5	230	360	50	350	450	148	N. fr., fair.
6	— 50	—(*)	—(*)	150	150	83	SE. br., sleet.
7	170	670	185	338	300	333	Var. br., cloudy.
8	—356	202	—128	89	—110	— 61	N. br., cloudy.
9	—600	—144	— 24	—300	—900	—394	N. lt., snow.
10	300	—148	22	185	150	102	W. br., snow, fair.
11	763	3,512	769	422	206	1,134	NW. br., snow, fair.
12	284	1,005	670	820	680	692	SE. fr., clear.
13	900	1,674	680	815	810	976	S. br., clear, snow.
14	210	220	700	690	700	504	Var. fr., clear.
15	104	— 43	—119	940	—104	156	W. br., snow, rain.
16	250	545	640	—210	—290	187	Var. lt., cloudy.
17	249	(*)	(*)	3,436	—2,990	232	SE. high, snow.
18	859	546	866	770	2,366	1,081	NW. br., snow.
19	420	3,754	1,339	575	403	1,298	Do.
20	1,450	650	570	635	785	818	NW. fr., fair.
21	3,501	4,112	811	830	750	2,001	NW. high, fair, snow.
22	200	795	650	500	680	555	NW. fr., snow, fair.
23	1,062	730	1,600	2,725	2,290	1,681	S. fr., cloudy.
24	860	2,220	1,750	(*)	735	1,391	NW. br., snow, fair.
25	110	350	1,305	2,352	2,590	1,341	SE. br., fair.
26	3,000	(*)	(*)	(*)	(*)	3,000	NW. high, snow.
27	(*)	(*)	(*)	(*)	(*)	(*)	NW. high, fair.
28	(†)	(†)	(†)	(†)	(†)	(†)	NW. gale, fair.
29	880	630	252	295	480	507	NW. fr., cloudy.
30	700	340	300	219	410	394	NW. lt., cloudy.
31	530	395	560	630	450	513	NW. fr., cloudy.
Sums	16,279	22,800	13,445	17,176	11,468	18,999	
Means	581	877	517	636	410	655	NW. br., snow.

†Omitted.

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N. Y.*—Cont'd.

OCTOBER, 1887, TO AUGUST, 1888, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

FEBRUARY, 1888.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1	522	270	205	430	305	346	Var. gen., snow.
2	215	198	332	210	250	241	NW. lt., cloudy.
3	550	120	155	550	350	345	N. fr., cloudy.
4	—1,039	—2,605	— 520	—2,610	—2,629	—1,881	SE. br., sleet, rain.
5	260	245	250	310	525	318	N. fr., threatening.
6	315	330	310	290	180	285	NW. fr., cloudy.
7	639	814	740	1,679	150	804	SE. br., cloudy, snow.
8	800	(*)	(*)	490	450	580	N. fr., cloudy, snow.
9	575	300	205	50	250	276	NW. fr., cloudy.
10	1,010	350	61	— 175	2,003	650	SE. br., cloudy.
11	1,000	380	885	1,400	1,004	1,034	NW. fr., cloudy.
12	915	1,210	890	895	970	976	SE. fr., fair.
13	950	915	815	650	500	766	S. fr., clear.
14	810	540	365	400	170	457	SW. fr., fair.
15	(*)	(*)	(*)	(*)	(*)	(*)	NW. high, snow.
16	330	380	520	620	260	422	SW. fr., fair.
17	202	400	518	532	483	427	NW. fr., cloudy.
18	643	656	330	476	560	533	N. lt., snow, fog, cloudy.
19	525	690	741	612	420	598	SE. br., cloudy.
20	— 742	321	380	260	205	85	S. br., cloudy.
21	— 240	— 170	— 871	80	160	— 208	N. fr., cloudy.
22	— 371	— 160	— 110	— 640	—1,050	— 466	NW. fr.. snow, clear.
23	640	500	550	408	370	494	S. fr., fair.
24	320	400	360	600	430	422	Do.
25	—2,046	—2,601	165	80	250	— 830	SE. br , sleet, rain, cloudy.
26	534	799	220	370	207	426	S. fr., fair.
27	—1,690	— 138	—1,049	—1,278	— 941	—1,028	NW. fr., snow, cloudy.
28	2,442	779	150	205	— 566	602	NW. fr., cloudy.
29	308	278	— 538	—1,050	173	— 166	N. gen., cloudy.
Sums	8,377	5,701	6,014	5,844	5,439	6,508	
Means	299	211	223	209	194	232	NW. fr., cloudy.

MARCH, 1888.

1	708	478	— 539	400	170	243	N. lt., cloudy, snow.
2	—1,535	623	589	— 601	— 43	— 193	SE. br., rain.
3	(*)	957	1,423	1,106	(*)	1,162	NW. high, snow.
4	1,191	2,428	1,953	1,700	2,099	1,874	NW. br., fair.
5	895	760	590	680	410	667	N. fr., cloudy.
6	550	410	125	150	350	315	NW. fr., cloudy.
7	671	471	430	430	246	450	Do.
8	156	527	980	765	400	566	NW. br., cloudy, snow.
9	610	600	850	750	760	714	N. fr., clear.
10	1,640	1,031	765	947	600	997	S. br., cloudy.
11	685	800	708	82	(*)	596	S. br., rain, snow.
12	(*)	(*)	(*)	(*)	(*)	(*)	N. high, snow.
13	— (*)	— (*)	— (*)	— (*)	— (*)	— (*)	Do.
14	980	1,110	640	215	410	671	N. br., snow, cloudy.
15	160	93	254	410	609	305	N. fr., cloudy.
16	321	146	— 89	150	103	126	NW., fr., cloudy, snow.
17	1,979	2,098	382	600	717	1,155	N. fr., fair, snow.
18	909	870	830	740	601	790	N. lt., clear.
19	877	1,250	880	810	1,030	969	SE. br., clear.
20	350	186	350	— 71	259	215	S. br., cloudy.
21	— 135	106	— 610	— 350	—1,489	— 496	NW., high, cloudy.
22	—2,238	—1,913	(*)	—1,105	108	—1,287	NW. br., cloudy, snow.
23	33	— 341	— 329	— 189	— 530	— 271	NW. high, fair.
24	260	— 341	— 942	— 221	— 513	— 351	NW. br., fair.
25	316	537	239	478	491	412	SE. fr., clear.
26	53	— (*)	— (*)	648	216	306	SE. high, rain, cloudy.
27	1,110	980	649	600	460	758	SE. br., cloudy.
28	689	248	554	435	39	393	SE. fr., cloudy.
29	—1,274	—1,687	—1,234	—1,465	— 579	—1,248	NW. fr., fair.
30	— 340	—2,709	— 778	18	238	— 714	SE. fr., rain, snow, fair.
31	— 225	— 136	— 671	— 574	— 235	— 368	NW. br., fair.
Sums	9,396	9,582	7,999	7,538	6,927	8,756	
Means	336	342	296	260	257	302	NW. br., cloudy.

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N. Y.*—Cont'd.

OCTOBER, 1887, TO AUGUST, 1888, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

APRIL, 1888.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1	— 575	— 1,378	— 50	64	(*)	— 485	SE. fr., cloudy, rain.
2	— 1,296	— 868	— 955	— 910	— 360	— 878	NW. fr., fog, rain.
3	— 459	— 1,060	— 852	— 366	— 1,635	— 874	NW. fr., fair.
4	72	487	302	1,015	531	481	NW. fr., clear.
5	1,420	(*)	(*)	— 1	1,430	950	SE. br., rain, cloudy.
6	— 1,090	— 1,925	— 750	— 548	— 17	— 868	NW. br., clear.
7	— 402	— 2,382	— 768	— 462	— 1,058	— 1,014	Do.
8	— 1,190	— 1,432	— 476	— 662	— 690	— 890	NW. fr., clear.
9	312	164	148	219	255	220	SE. fr., clear.
10	199	— 1,109	— 1,697	— 200	116	— 538	SE. high, rain.
11	— 430	— 351	— 195	— 340	— 388	— 341	NW. br., cloudy.
12	170	— 76	— 316	92	— 724	— 171	N. br., cloudy, snow.
13	— 422	— 338	— 616	— 743	224	— 379	NW. fr., clear.
14	— 240	— 369	— 523	— 600	— 740	— 494	NW. fr., rain.
15	— 649	— 810	— 1,020	— 745	— 295	— 704	NW. fr., cloudy.
16	103	— 27	29	— 4	— 333	— 46	NW. fr., clear.
17	— 746	— 598	— 751	— 473	— 1,638	— 845	NW. lt., fair.
18	— 1,786	480	— 75	124	— 1,238	— 499	NW. br., fair.
19	162	— 512	— 704	— 885	— 1,150	— 618	NW. lt., fair, hazy.
20	— 1,308	42	— 458	— 248	— 990	— 592	NW. br., cloudy, snow.
21	— 311	— 97	— 610	— 325	— 165	— 302	Do.
22	— 124	— 583	— 425	— 297	— 268	— 339	NW. fr, fair, clear.
23	444	— 844	— 303	37	79	— 117	NW. br., fair, cloudy.
24	— 287	148	35	— 42	— 140	— 57	NW. br., cloudy.
25	— 262	62	710	— 976	— 681	— 513	N. lt., clear.
26	276	166	— 617	— 252	— 20	— 90	NW. lt., clear.
27	250	179	— 300	— 121	270	56	Do.
28	— 46	89	119	244	350	151	Do.
29	111	200	145	125	208	158	NW. fr., clear.
30	— 1,851	— 920	15	— 245	— 50	— 610	NW. fr., hazy.
Sums	—10,069	—14,636	—11,562	—9,555	—10,179	—11,250	
Means	— 336	— 505	— 399	— 318	— 351	— 375	NW. fr., clear.

MAY, 1888.

1	— 266	— 161	— 636	— 214	— 350	— 325	NW. fr., cloudy.
2	185	19	300	100	100	87	N. br., cloudy, fair.
3	260	445	280	335	203	305	S. fr., fair.
4	208	206	320	168	250	230	S. high, fair, clear.
5	241	282	— 18	68	— 150	85	W. fr., fair, cloudy.
6	330	(†)	— 372	140	321	105	N. fr., clear.
7	255	293	270	133	65	203	NW. fr., cloudy.
8	138	— 541	150	428	409	117	SE. br., cloudy, rain.
9	212	450	350	330	240	316	S. fr., fair.
10	260	260	316	— 588	494	148	SW. lt., cloudy, rain.
11	305	320	300	325	280	306	S. br., cloudy.
12	101	— 247	— 70	— 238	1,035	116	SSE. fr., cloudy.
13	— 225	— 304	— 142	— 260	— 159	— 218	SW. fr., fair, clear, cl'y.
14	— 669	— 680	—1,650	— 275	—1,076	— 870	N. fr., rain, cloudy.
15	— 468	— 576	— 267	— 86	— 71	— 294	NW. lt., cloudy, rain.
16	120	220	349	— 759	328	52	NW. lt., rain, cloudy,
17	22	186	180	72	— 133	65	N. fr.. fair. [fair.
18	210	— 261	201	482	234	173	SE. fr., rain.
19	202	— 163	— 506	— 862	— 178	— 301	NW. fr., cloudy.
20	160	120	130	168	246	165	NW. br., cloudy, fair.
21	— 327	— 343	18	— 247	— 540	— 293	NW. fr., clear.
22	250	389	355	325	514	367	SSW. fr., clear, fair.
23	406	360	331	141	156	279	ESE. fr., fair, cloudy.
24	330	320	350	242	246	308	E. fr., cloudy.
25	389	397	321	272	36	283	SE. fr., cloudy, rain.
26	270	265	200	90	39	173	SE. fr., cloudy.
27	153	— 30	— 72	40	— 140	— 10	SE. lt., cloudy.
28	—(*)	742	280	230	258	378	S. br., cloudy, rain.
29	— 124	21	200	120	40	51	N. lt., cloudy, rain, fair.
30	242	190	120	160	230	188	NW. lt., cloudy, fair.
31	230	117	315	1,464	1,380	701	S. lt., fair, cloudy, rain.
Sums	3,400	2,296	1,903	2,301	4,307	2,890	S. fr., cloudy.
Means	113	77	61	74	139	93	

† Omitted.

TABLE B.—*Daily observations with hourly, daily, mo nthly, and annual means, Ithaca, N. Y.*—Cont'd.

OCTOBER, 1887, TO AUGUST, 1888, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

JUNE, 1888.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1	26	97	— 162	— 230	— 672	—188	NW. br., clear.
2	269	—433	— 42	— (*)	954	187	NW. fr., cloudy, rain.
3	164	190	140	190	265	190	NW. fr., clear.
4	290	—108	110	70	120	96	Do.
5	250	300	350	280	180	272	SW. fr., clear.
6	250	240	210	175	1,115	398	S. fr., fair.
7	— 49	— 40	— 110	— 2	87	— 23	NW. fr., cloudy.
8	280	149	210	270	110	204	NW. lt., clear.
9	275	230	280	250	230	253	S. br., clear.
10	209	200	170	210	110	180	S. fr., cloudy, fair.
11	240	— 90	— 140	— 95	100	3	NW. br., cloudy, rain, clear.
12	20	112	44	96	160	86	N. fr., fair.
13	230	68	199	180	180	171	S. br., fair, cloudy.
14	310	200	120	200	160	198	N and S. fr., cloudy, fair.
15	100	250	200	140	190	176	W. br., rain, fair.
16	100	15	61	154	230	112	N. fr., clear.
17	95	126	95	90	120	105	NW. lt., clear.
18	130	350	145	220	282	225	NW. br., fair.
19	230	295	220	260	310	263	NW. lt., clear.
20	210	180	150	280	280	220	NW. fr., fair.
21	140	186	124	160	241	170	NE. lt., clear, cloudy.
22	210	240	180	210	261	220	W. lt., fair.
23	200	82	3,486	136	110	803	S. lt., fair, rain, cloudy.
24	242	210	184	3,068	75	756	NW. lt., fair, rain, cloudy.
25	210	141	198	203	58	162	NW. fr., clear.
26	49	191	142	216	230	166	NW. fr., rain, fair.
27	190	321	200	255	157	225	NW. fr., clear.
28	130	140	170	100	90	126	SE. br., rain.
29	80	110	66	70	100	85	NW. lt., rain, cloudy.
30	82	— 24	142	182	106	99	NW. fr., cloudy.
Sums	5,162	3,932	7,142	7,338	6,079	5,940	NW. fr., clear.
Mean	172	131	238	253	203	198	

JULY, 1888.

1	100	103	60	140	162	113	NW. br., fair.
2	178	148	128	210	115	156	N. lt., fair.
3	205	205	197	200	227	207	S. fr., clear.
4	215	220	160	168	160	185	SW. br., clear.
5	465	140	—769	110	165	22	S. fr., cloudy, rain, clear.
6	330	350	230	210	295	283	NW. fr., clear.
7	240	249	264	218	214	237	NW. br., clear.
8	100	72	—160	— 74	—110	— 34	NW. fr., clear, hazy.
9	200	251	116	61	47	135	NW. lt., cloudy.
10	70	360	190	228	320	234	NW. lt., clear.
11	320	194	— 90	—212	234	89	SW. br., clear, fair.
12	578	560	562	380	262	468	W. br., clear.
13	202	260	215	188	190	211	NW. br., cloudy, fair.
14	491	358	222	232	195	300	NW. fr., clear.
15	90	— 8	20	145	210	91	NW. fr., hazy, clear.
16	110	200	150	150	170	156	NW. fr., clear.
17	60	115	108	110	60	91	SW. br., hazy, fair.
18	60	60	—150	— 72	578	95	S. br., cloudy, rain.
19	180	8	185	0	74	89	S. fr., cloudy, rain.
20	165	120	165	188	225	173	NW. fr., clear.
21	242	110	107	120	185	153	Do.
22	160	180	215	145	90	158	NW. lt., clear.
23	145	90	160	170	160	145	NW. fr., fair.
24	135	108	166	230	220	172	NW. br., clear.
25	20	— 30	95	108	156	70	NW. fr., clear.
26	90	85	95	110	50	86	S. fr., cloudy, rain.
27	102	258	164	210	230	193	NW. fr., fair.
28	127	120	90	40	80	91	Do.
29	110	130	100	110	170	124	NW. fr., clear.
30	100	145	125	155	270	159	SE. fr., hazy, clear.
31	170	135	130	—188	155	80	SW. and NW. fr., cloudy, rain.
Sums	5,760	5,326	3,300	3,780	5,559	4,732	NW. fr., clear.
Mean	186	172	106	122	179	153	

TABLE B.—*Daily observations with hourly, daily, monthly, and annual means, Ithaca, N.Y.*—Cont'd.

OCTOBER, 1887, TO AUGUST, 1888, INCLUSIVE.

[An asterisk (*) indicates "beyond the range of the electrometer," usually accompanied by sparking between needle and quadrants.]

AUGUST, 1888.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1	350	100	100	190	210	190	NW. fr., clear.
2	— 8	200	200	240	260	178	Do.
3	160	140	120	200	210	146	SW. fr., fair.
4	360	70	120	170	—395	65	SEN. fr., fair.
5	160	220	140	— 90	190	124	NW. fr., cloudy.
6	110	120	170	200	210	162	NW. lt., fair.
7	160	190	190	140	150	166	NW. fr., clear.
8	190	140	140	160	150	156	SW. fr., fair.
9	150	155	200	255	220	156	NW. fr., clear.
10	210	200	225	230	165	204	Do.
11	280	60	110	280	225	191	NW. lt., cloudy, rain.
12	— 45	100	125	195	205	116	NW. fr., rain, cloudy.
13	—170	265	160	250	270	155	NW. high, rain, cloudy, fair.
14	340	— 10	110	100	20	112	NW. lt., clear, fair.
15	60	140	180	270	210	172	SW. fr., cloudy, hazy.
16	190	100	60	180	165	139	SWNW. fr., fair.
17	190	180	190	145	190	179	SNW. fr., rain, cloudy, fair.
18	100	90	120	130	180	124	NW. fr., cloudy.
19	215	220	200	230	270	227	S. fr., clear.
20	185	200	210	200	175	194	N. fr., cloudy.
21	200	200	180	180	110	174	S. fr., cloudy, rain.
22	50	90	120	140	170	134	NW. fr., rain, cloudy.
23	160	175	— 10	140	160	125	NW. fr., fair, rain, cloudy.
24	300	265	190	180	190	225	WSW. fr., clear.
25	— 15	75	120	200	130	102	W. fr., clear.
26	190	160	100	130	92	134	SW. fr., clear.
27	115	148	180	220	260	183	NW. fr., fair.
28	280	270	220	230	370	274	N. fr., clear.
29	290	310	230	280	395	301	NW. fr., clear.
30	390	395	240	360	340	345	SW. fr., fair.
31	365	310	255	—110	— 70	150	S. fr., cloudy.
Sums	5,512	5,270	4,795	5,625	5,427	5,303	NW. fr., clear.
Means	178	170	155	181	175	171	

SUMMARY.

Months.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
October, 1887	311	241	206	232	244	247	W. fr., cloudy.
November, 1887	233	262	141	295	263	242	NW. br., cloudy.
December, 1887	453	682	508	461	506	534	NWSE. fr., cloudy.
January, 1888	581	877	517	636	410	655	NW. br., snow.
February, 1888	299	211	223	209	194	232	NW. fr., cloudy.
March, 1888	336	342	296	260	257	302	NW. br., cloudy.
April, 1888	—336	—505	—399	—318	—351	—375	NW. fr., clear.
May, 1888	113	77	61	74	139	93	S. fr., cloudy.
June, 1888	172	131	238	253	203	198	NW. fr., clear.
July, 1888	186	172	106	122	179	153	Do.
August, 1888	178	170	155	181	175	171	Do.
Sums	2,526	2,660	2,052	2,405	2,219	2,452	
Means	229	242	187	219	202	223	NW. fr., cloudy.

TABLE C.—*Daily observations with hourly, daily, monthly, and annual means. New Haven, Conn., August* 1, 1886, *to July* 31, 1887.

AUGUST, 1886.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
2	4.3	6.9	0.2	12.3	+5.9	NW. lt., cloudy, rain, 12.25–12.58 [p. m.
3	10.8	11.0	11.4	6.2	9.8	W. lt., cloudy.
4	10.6	10.3	7.2	13.5	10.4	W. lt., fair.
5	21.2	32.6	9.7	3.2	16.7	S. lt., cloudy.
6	23.2	16.9	18.6	21.9	20.2	SE. lt., cloudy.
7	9.8	12.9	2.6	—20.5	1.2	NE. lt., cloudy.
9	11.5	19.6	20.9	54.3	26.6	SW. lt., clear.
10	14.0	18.2	12.8	15.4	15.1	SW. lt., fair.
11	1.7	3.0	8.4	8.5	5.4	SW. lt., cloudy.
12	—15.3	13.4	6.5	10.7	3.8	NW. lt., cloudy.
13	13.9	10.5	— 0.6	4.7	7.1	S., fair.
14	4.0	9.8	14.3	24.1	13.0	W., fair.
16	15.2	11.7	— 0.6	1.2	6.9	
17	6.7	10.6	9.6	10.9	9.4	N., fair.
18	19.3	11.5	11.4	14.2	14.1	NE., cloudy.
19	10.1	.....	.....	.....	10.1	
Sums	161.0	198.9	132.4	180.6	175.7	
Means	10.1	13.3	8.8	12.0	11.0	

SEPTEMBER, 1886.

20	8.3	4.5	.....	5.2	6.0	NW., fair.
21	13.6	10.6	8.5	7.6	10.1	Do.
22	17.9	16.5	5.7	10.9	12.8	SW., cloudy.
23	80.0	5.3	22.9	25.9	33.5	Var., cloudy, lt. rain.
24	36.4	51.5	60.3	36.6	46.2	Var., fair.
25	35.7	16.6	10.6	.....	21.0	E., cloudy.
27	4.0	2.4	2.3	1.7	2.6	SW., cloudy.
28	2.7	7.6	5.4	3.0	4.7	NE., cloudy.
29	10.4	14.0	25.0	22.5	18.0	NW., lt. rain, cloudy.
Sums	209.0	139.0	140.7	113.4	154.9	
Means	23.2	14.3	17.6	14.2	17.2	

OCTOBER, 1886.

1	41.5	37.3	9.1	16.7	26.2	NW., fair.
4	41.8	20.0	38.5	29.2	32.4	SW., clear.
5	33.7	10.4	10.6	7.0	15.4	NE., clear.
6	13.3	10.9	10.7	8.6	10.9	NE., fair.
7	1.7	2.9	3.3	.....	2.6	NE., clear.
8	16.2	17.4	12.5	.....	15.4	Var., clear.
9	31.8	9.6	9.9	9.7	15.2	S., clear.
11	18.6	10.4	22.4	11.8	15.8	Do.
12	10.8	24.7	33.9	15.7	21.3	W., clear.
13	19.3	20.2	.....	10.8	16.8	E., cloudy.
14	9.8	12.6	10.3	11.3	11.0	SE., cloudy.
15	11.8	10.9	6.8	7.8	9.3	W., cloudy.
16	9.9	11.1	9.6	.....	10.2	W., fair.
18	— 1.7	24.5	19.0	21.0	15.7	W., hvy. rain, cloudy.
19	21.6	20.7	27.6	16.9	21.7	S., cloudy.
20	39.4	21.4	32.0	27.7	30.1	S., fair.
21	10.0	18.1	14.2	— 3.6	9.7	NW., lt. rain, clear.
22	16.4	14.1	17.5	15.4	15.8	W., clear.
23	38.6	17.8	14.0	.....	23.5	Var., clear.
25	9.7	7.7	17.5	13.1	12.0	SW., cloudy.
26	— 11.3	6.9	10.3	2.7	2.2	NE., cloudy.
27	—146.8	6.3	61.9	.....	—26.2	NE., lt. rain.
28	17.5	34.7	9.3	12.7	18.6	NE., cloudy, lt. rain.
29	15.5	11.6	11.1	9.5	11.9	NE., cloudy.
30	2.7	5.7	0.7	1.3	2.6	NE., threatening.
Sums	271.8	387.9	412.7	245.3	340.1	
Means	10.8	15.5	17.2	12.3	13.6	NE., cloudy.

TABLE C.—*Daily observations with hourly, daily, monthly, and annual means, New Haven, Conn., August* 1, 1886, *to July* 31, 1887—Continued.

NOVEMBER, 1886.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1	28.1	50.7	54.3	29.3	40.6	N., clear.
2	55.0	39.0	37.3	77.3	52.2	N., fair.
3	13.5	26.8	53.3	32.7	31.6	S., fair.
4	25.4	13.5	9.7	6.6	13.8	NW., fair.
5	77.1	31.1	17.2	27.3	38.2	S., clear.
6	70.0	— 17.5	15.3	24.7	23.1	S., lt. rain, cloudy.
8	11.9	12.0	18.5	12.6	13.8	W., fair.
9	13.4	14.6	17.0	17.2	15.6	SW., clear.
10	28.4	— 18.4	3.7	27.9	10.4	SW., cloudy, lt. rain.
11	32.9	26.3	20.0	11.4	22.7	W., fair.
12	9.0	11.9	5.3	— 39.4	— 3.3	N., cloudy, lt. rain.
13	6.2	1.3	1.0	2.5	2.8	N., cloudy.
15	10.0	8.9	9.5	14.4	10.7	NW., clear.
16	12.3	41.2	15.9	14.0	20.8	NW., fair.
17	— 6.7	41.3	24.9	33.1	23.2	NE., lt. rain.
18	23.9	26.7	0.2	9.5	15.1	W., cloudy, rain.
19	11.7	19.7	23.1	24.3	19.7	W., cloudy, fair.
20	25.5	.....	33.2	28.2	28.9	SW., clear.
22	19.2	18.7	19.3	15.4	18.2	NW., clear.
23	—116.0	12.4	8.0	14.3	—20.3	E., lt. rain.
24	17.2	12.9	27.2	16.4	18.4	W., fair.
25	17.5	9.4	5.8	7.8	10.1	NE., cloudy, lt. rain.
26	18.1	22.0	17.6	15.6	18.3	W., clear, cloudy.
27	65.9	57.9	18.4	11.8	38.5	SW., clear.
29	41.2	30.6	20.0	21.2	28.2	SW., fair.
30	30.9	19.4	29.2	27.4	26.7	NE., cloudy.
Sums	541.5	512.4	504.9	484.5	518.0	
Means	20.8	20.5	19.4	18.6	19.9	W., cloudy.

DECEMBER, 1886.

1	24.6	15.3	26.3	32.9	24.8	W., cloudy.
2	11.8	66.8	.....	10.8	29.8	NW., clear.
3	26.8	13.6	39.8	36.8	29.2	Do.
4	28.4	22.9	10.6	.....	20.6	NW., fair.
6	9.9	11.1	14.4	14.7	12.5	N., cloudy.
7	— 8.8	— 7.0	25.7	540.0	137.5	NE., snow.
8	38.1	33.0	44.8	5.8	30.4	NW., clear.
9	56.0	46.0	28.3	38.2	42.1	Do.
10	67.0	52.5	65.4	53.4	59.6	W., clear.
11	37.5	.....	40.6	40.4	39.5	Do.
13	24.6	21.5	— 57.0	19.3	2.1	NE. lt., rain.
14	40.6	28.7	30.8	25.4	31.4	NW., fair.
15	17.6	7.8	— 5.1	— 68.8	—12.1	W. lt., rain.
16	1,307.0	957.0	295.0	30.9	647.5	N., snow, fair.
17	61.0	102.0	34.0	50.6	61.9	SW., clear.
18	— 39.0	—108.5	50.3	.....	—32.4	SW. lt., rain.
20	71.0	21.6	17.9	18.9	32.3	N., fair.
21	30.9	59.4	49.8	47.5	46.9	W., clear.
22	75.6	27.9	81.8	38.2	55.9	N., cloudy.
23	66.0	37.0	41.8	28.2	43.2	NE., fair.
24	60.0	22.5	22.6	22.7	31.9	SE., fog, lt. rain.
25	11.0	14.7	11.8	13.1	12.6	NW., clear.
27	21.9	18.2	33.7	8.5	20.6	W., snow, clear.
28	27.2	17.4	17.4	16.4	19.6	W., fair.
29	24.6	31.7	14.9	10.2	20.3	W., cloudy.
30	88.9	85.0	88.8	31.6	73.6	NE. lt., snow.
31	— 67.6	— 53.4	— 69.6	—125.0	—78.9	NE., sleet, rain.
Sums	2,112.6	1,544.7	954.8	940.7	1402.4	
Means	78.2	59.4	36.7	37.6	51.9	W., cloudy.

TABLE C.—*Daily observations with hourly, daily, monthly, and annual means, New Haven, Conn., August* 1, 1886 *to July* 31, 1887—Continued.

JANUARY, 1887.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1	16.4	— 96.6	3.3	19.4	—14.4	NE., rain, fog.
3	36.0	32.6	31.5	34.4	33.6	NW., clear.
4	55.7	76.9	59.7	40.6	58.2	NE., clear.
5	56.6	46.0	38.9	21.1	40.6	NE., cloudy, snow.
6	30.9	45.7	40.7	21.6	34.7	NW., fair.
7	49.3	27.5	20.0	17.0	28.4	Do.
8	12.8	14.5	24.4	38.3	22.5	NE., clear, hazy.
10	35.2	27.8	15.9	6.2	21.3	NW., fair.
11	28.0	32.2	28.5	10.2	24.7	W., clear.
12	24.7	25.9	25.9	38.8	28.8	SW., fair.
13	51.4	33.2	22.6	66.9	43.5	W., hazy, clear.
14	—39.9	27.7	39.9	2.2	7.5	N., rain, cloudy.
15	20.1	13.4	27.6	23.7	21.2	NE., cloudy, snow.
17	—22.3	—146.2	9.0	28.3	—32.8	NE., lt. rain.
18	67.7	44.4	21.7	39.4	43.3	W., clear.
19	42.6	34.9	28.2	22.0	31.9	W., clear, cloudy.
20	32.4	87.1	57.1	43.9	55.1	Var., cloudy.
21	45.9	34.0	16.2	16.0	28.0	W., fair.
22	7.2	18.4	28.1	34.7	22.1	NE., cloudy.
24	—10.7	— 57.0	—96.6	2.4	—40.5	SW., lt. rain, hvy. rain.
25	43.7	44.3	54.4	31.8	43.6	S., cloudy.
26	27.0	11.3	—77.2	37.6	—00.3	N., cloudy, snow.
27	26.2	28.5	26.9	28.1	27.4	NW., clear.
28	54.4	27.7	24.3	25.5	33.0	SW., cloudy.
29	13.7	11.0	—44.8	—52.8	—18.2	SW., cloudy, hvy. rain.
31	28.8	15.4	16.0	17.2	19.3	NW., fair.
Sums	733.8	460.6	442.2	614.5	562.5	
Means	28.2	17.7	17.0	23.6	21.6	NE., cloudy.

FEBRUARY, 1887.

1	12.0	17.9	26.6	25.6	20.5	N., cloudy.
2	—394.3	402.9	27.6	10.6	11.7	NE., snow, cloudy.
3	11.6	16.3	19.7	2.0	12.4	N., cloudy, snow, rain.
4	17.6	19.2	16.8	.....	17.9	NW., fair.
5	29.9	34.4	40.1	31.7	34.0	N., fair.
7	— 3.5	4.9	11.4	—24.8	— 3.0	NE., cloudy, sleet.
8	— 1.1	— 11.8	7.9	25.4	5.1	E. lt., rain.
9	16.9	16.8	14.2	17.0	16.2	NW., clear.
10	82.8	32.4	16.6	36.4	42.0	SW., fair.
11	93.0	23.8	20.0	9.2	36.5	SW., foggy, threatening.
12	14.2	13.6	12.4	17.0	14.3	NW., clear.
14	22.5	28.5	24.5	18.6	23.5	NE., clear.
15	— 53.7	10.7	18.0	30.1	1.3	SW., hvy. rain, lt. rain.
16	79.4	27.0	26.4	15.4	37.0	NW., cloudy.
17	33.2	13.6	11.6	11.8	17.6	NW., fair.
18	— 91.3	9.4	81.6	—14.2	— 3.6	E., sleet, cloudy, lt. rain.
19	10.7	13.0	20.9	15.2	15.0	W., clear.
21	22.6	20.2	28.6	31.8	25.8	N., cloudy.
22	198.0	—111.0	13.0	13.6	28.4	SE., hvy. snow, lt. rain.
23	40.8	19.8	18.2	22.2	25.2	NE., cloudy.
24	20.8	14.3	10.7	13.6	14.8	W., lt., rain, cloudy.
25	12.1	16.6	12.7	16.6	14.5	NW., clear.
26	20.4	20.4	65.2	41.6	36.9	NE., cloudy, hvy. snow.
27	13.0	.....	11.2	.....	12.1	W., fair.
28	66.0	37.8	15.8	11.8	32.8	Do.
Sums	153.9	680.7	561.7	378.2	488.9	
Means	6.2	28.4	22.5	16.4	19.6	NW., cloudy.

TABLE C.—*Daily observations with hourly, daily, monthly, and annual means, New Haven, Conn., August* 1, 1886, *to July* 31, 1887—Continued.

MARCH, 1887.

Day of month.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1	14.0	13.2	16.2	13.8	14.3	N., cloudy, snow, fair.
2	12.4	10.8	15.8	18.8	14.4	SW., cloudy.
3	6.9	16.2	14.2	10.9	12.0	NE., fair.
4	38.0	28.0	33.6	16.8	29.1	N., cloudy.
5	52.5	40.6	37.8	36.2	41.8	NE., clear, cloudy.
7	47.3	47.2	30.3	51.0	44.0	E., clear.
8	22.3	16.0	12.3	11.9	15.6	N., clear.
9	30.8	20.6	20.2	14.2	21.4	SE., clear.
10	— 81.4	—136.2	11.0	9.0	— 49.4	N., hvy. and lt. rain, cloudy.
11	13.3	14.8	14.1	17.8	15.0	N., fair.
12	13.9	16.8	21.7	19.8	18.0	N., cloudy, clear.
14	20.6	17.8	18.2	17.4	18.5	N., clear, hazy, cloudy.
15	6.1	11.2	19.8	15.7	13.2	NW., clear.
16	12.4	18.5	21.2	23.1	18.8	NW., fair.
17	18.1	24.4	24.5	20.7	21.9	NW., cloudy.
18	14.7	22.5	23.5	25.2	21.5	Do.
19	17.1	17.5	21.9	15.2	17.9	N., fair.
21	36.8	45.8	26.6	22.2	32.8	SE., fair.
22	—135.4	22.0	3.8	94.2	— 3.8	NE., hvy. and lt. rain, sleet.
23	17.4	32.8	26.5	13.6	22.6	W., cloudy.
24	18.6	23.7	19.4	20.5	20.6	SW., clear.
25	34.5	39.6	25.4	17.3	29.2	W., clear.
26	19.1	26.0	26.6	28.3	25.0	N., clear.
28	—104.0	7.7	15.4	35.6	— 11.3	NE., lt. rain, cloudy.
29	10.3	25.0	13.8	9.7	14.7	NW., cloudy.
30	16.4	31.0	28.8	20.5	24.2	W., fair.
31	7.4	32.5	6.0	16.4	15.6	S., clear, cloudy.
Sums	180.1	486.0	548.6	615.8	457.6	
Means	6.7	18.0	20.3	22.8	16.9	N., cloudy.

APRIL, 1887.

1	65.6	49.8	8.4	12.1	34.0	NE., lt. snow.
2	166.0	88.5	22.8	151.0	107.1	Do.
4	27.5	13.1	17.5	5.7	16.0	SW., fair.
5	10.3	10.6	6.7	8.1	8.9	W., cloudy.
6	10.4	1.4	6.1	7.8	6.4	NW., clear.
7	26.6	4.2	4.9	3.6	9.8	NW., fair
8	28.1	21.8	19.5	21.0	22.6	S., clear.
9	18.4	19.5	14.6	17.2	17.4	SW., cloudy.
11	7.0	24.2	3.9	1.6	9.2	W., fair.
12	19.0	9.6	18.4	9.0	14.0	S., cloudy.
13	4.4	12.0	9.0	7.7	8.3	NE., cloudy.
14	14.1	4.7	— 9.3	5.7	3.8	Var., cloudy.
15	17.4	6.0	4.1	— 7.0	5.1	E., cloudy.
16	5.7	12.9	24.1	25.4	17.0	NW., cloudy.
18	—17.0	—42.9	24.9	26.3	— 2.2	NE., cloudy, lt. snow, sleet.
19	27.6	13.1	9.5	13.4	15.9	NW., cloudy, clear.
20	19.8	17.6	23.0	17.6	19.5	Var., fair.
21	31.0	15.7	12.2	11.1	17.5	SE., fair.
22	30.8	28.2	10.2	32.0	25.3	S., fair.
23	0.6	26.8	9.8	19.0	14.0	E., lt. rain.
25	19.8	17.2	16.6	21.8	18.8	SE., clear, cloudy.
26	—74.8	11.4	7.7	58.2	0.6	W. lt. rain, cloudy.
27	63.4	19.4	24.4	—13.8	23.4	SW., cloudy.
28	— 2.6	26.6	16.8	1.0	10.4	E., lt. rain, cloudy.
29	29.4	5.8	— 3.0	94.0	31.6	SW., cloudy.
30	30.8	12.2	3.6	2.6	12.3	NW., cloudy.
Sums	579.3	429.4	304.4	552.1	466.8	
Means	22.3	16.5	11.7	21.2	18.0	NW., cloudy.

NOTE.—On and after April 19 observations were made at 7 a. m. instead of 9 a. m.

TABLE C.—*Daily observations with hourly, daily, monthly, and annual means, New Haven, Conn., August* 1, 1886, *to July*, 31, 1887—Continued.

MAY, 1887.

Day of month.	7 a.m.	11 a.m.	1 p.m.	3 p.m.	Means.	Remarks.
2	18.2	10.8	10.2	15.6	13.7	SE., clear, cloudy.
3	19.8	6.1	5.6	6.5	9.5	E., cloudy.
4	21.2	28.2	19.0	—13.3	13.8	S., cloudy.
5	8.8	11.7	5.5	5.9	8.0	Do.
6	8.5	7.3	19.7	5.2	10.2	E., cloudy.
7	5.6	— 8.0	0.3	—13.7	— 4.0	Do.
9	28.1	28.3	26.5	16.8	24.9	S., cloudy.
10	28.3	31.2	34.0	30.3	31.0	S., fair.
11	13.7	— 5.4	0.6	— 0.9	2.0	N., clear.
12	— 2.1	— 2.0	—10.2	— 0.1	—3.6	N., cloudy, hazy.
13	7.8	13.7	5.9	16.4	11.0	N., clear.
14	10.4	6.9	6.2	25.8	12.3	NE., fair.
16	27.8	16.0	21.4	11.4	19.2	S., hazy.
17	3.0	7.4	7.0	5.2	5.6	Do.
18	34.0	8.2	8.6	13.0	16.0	SE., hazy.
19	18.4	1.6	—12.8	2.7	2.5	N., clear.
20	4.5	10.5	0.8	5.2	5.2	SW., hazy.
21	19.5	13.5	1.8	10.5	11.3	Do.
23	25.3	18.3	10.2	8.4	15.6	W., cloudy.
24	2.3	10.2	— 8.3	— 8.7	—1.1	S., cloudy, lt. rain, cloudy.
25	11.3	17.7	58.0	11.0	24.5	S., lt. rain, cloudy.
26	95.5	29.0	64.3	35.9	56.2	S., cloudy.
27	23.8	25.4	14.6	7.7	17.9	S., clear, 3-10 clouds.
28	— 4.4	2.6	4.1	5.3	1.9	NE., cloudy.
30	14.9	23.7	14.7	14.2	16.9	SE., cloudy.
31	13.7	7.6	1.6	3.8	6.7	E., cloudy.
Sums	457.9	320.5	308.4	220.8	327.2	
Means	17.6	12.3	11.9	8.5	12.1	S., cloudy.

JUNE, 1887.

1	—168.8	1.0	21.2	18.0	—32.1	E., hvy. rain, cloudy.
2	14.8	59.4	16.6	28.2	29.7	SE., lt. rain, cloudy.
3	19.0	31.3	22.0	14.8	21.8	SW., cloudy.
4	11.6	13.2	10.8	17.0	13.2	Var., cloudy.
6	16.4	21.3	35.6	36.0	27.3	SE., cloudy.
7	16.5	16.9	35.6	55.1	31.0	S., lt. rain, cloudy.
8	18.5	34.1	7.1	10.0	17.4	S., cloudy, lt. rain, cloudy.
9	10.8	0.9	2.5	9.4	5.9	NW., fair, cloudy.
10	17.5	15.9	16.4	13.0	15.7	E., cloudy.
11	16.0	15.4	11.5	41.5	21.1	NE., clear.
13	41.0	10.9	6.8	14.7	18.3	NE., fair.
14	18.0	8.7	4.0	6.7	9.3	Do.
15	25.0	20.1	36.5	18.5	25.0	S., clear.
16	18.4	6.7	4.4	14.0	10.9	SW., cloudy.
17	6.7	1.3	.....	16.7	8.3	S., cloudy, lt. rain.
18	35.3	13.1	26.3	22.0	24.2	S., cloudy, lt. rain, cloudy.
20	6.7	38.9	8.7	7.3	15.4	S., cloudy.
21	26.9	17.1	12.6	8.7	16.3	E., fog, hazy, cloudy.
22	28.7	29.1	6.0	15.1	19.7	S., cloudy, lt. rain, cloudy.
23	10.8	14.8	— 2.0	—342.0	—79.6	S., lt. rain, hvy. rain.
24	13.8	59.0	12.5	11.1	24.1	SW., cloudy.
25	8.7	13.4	9.5	9.3	10.2	S., fair.
27	9.5	7.4	7.0	.....	8.0	N., fair.
28	18.0	31.5	19.0	11.6	20.0	Var., fair.
29	24.6	55.5	10.5	24.0	28.6	S., clear.
30	27.0	26.8	6.5	9.1	17.4	W., clear.
Sums	291.4	563.7	357.6	89.8	327.1	
Means	11.2	21.7	14.3	3.5	12.6	S., cloudy.

TABLE C.—*Daily observations with hourly, daily, monthly, and annual means, New Haven, Conn., August* 1, 1886, *to July* 31, 1887—Continued.

JULY, 1887.

Day of month.	7 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1	10.9	28.5	33.0	22.5	23.7	SW., fair.
2	27.5	32.0	39.5	14.0	28.2	SW., clear.
4	13.0	4.1	6.8	7.5	7.9	SW., cloudy, clear.
5	13.0	4.5	11.5	5.2	8.6	S., cloudy.
6	88.5	4.7	1.7	2.2	24.3	S., lt. rain, cloudy.
7	5.9	1.5	1.2	3.8	3.1	W., cloudy, fair.
8	16.0	23.7	39.7	6.4	21.4	SW., fair.
9	28.2	20.3	24.3	12.5	21.3	S., cloudy.
11	61.5	9.4	4.5	11.7	21.8	NW., cloudy.
12	12.0	4.5	1.0	7.0	6.1	NW., fair.
13	—35.5	18.0	13.0	.....	—1.5	W., cloudy.
14	19.8	— 2.0	— 15.0	2.5	1.3	N., clear, fair.
15	14.5	5.5	5.0	9.0	8.5	NW., cloudy.
16	36.5	14.2	32.0	38.0	30.2	S., cloudy, clear.
18	50.5	27.6	—531.0	11.5	—110.4	NE., cloudy, lt. rain, cloudy.
19	17.2	99.5	23.0	.....	46.6	SE., cloudy.
20	17.5	22.7	29.0	20.0	22.3	S., cloudy, clear.
21	32.3	20.8	27.2	—209.3	—32.2	S., cloudy, lt. rain.
22	— 6.0	6.0	5.1	4.0	2.3	S., hvy. rain, cloudy.
23	10.7	2.7	3.0	.....	5.5	S., cloudy, lt. rain.
25	4.5	3.0	5.3	17.0	7.4	S., lt. rain, cloudy.
26	21.5	12.3	9.0	10.5	13.3	S., cloudy, fair.
27	17.5	22.5	16.5	10.5	16.8	Do.
28	23.5	28.5	17.0	19.5	22.1	S., cloudy, clear.
29	21.0	12.7	20.5	8.3	15.6	SW., cloudy.
30	4.5	7.0	9.5	9.9	7.7	S., cloudy.
Sums	526.5	434.2	—167.7	44.2	221.9	
Means	20.2	16.7	— 6.5	1.9	8.5	S., cloudy.

SUMMARY MEAN POTENTIAL AT NEW HAVEN.

Months.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.
August, 1886	161.0	198.9	132.4	180.6	168.2
September, 1886	209.0	139.0	140.7	113.4	150.5
October, 1886	271.8	387.9	412.7	245.3	329.4
November, 1886	541.5	512.4	504.9	484.5	510.8
December, 1886	2,112.6	1,544.6	954.8	940.7	1,388.2
January, 1887	733.8	460.6	442.2	614.5	562.8
February, 1887	153.9	680.7	561.7	378.2	443.6
March, 1887	180.1	486.0	548.6	615.8	457.6
April, 1887	*579.3	429.4	304.4	552.1	466.3
May, 1887	457.9	320.5	308.4	220.8	326.9
June, 1887	291.4	563.7	357.6	89.8	325.6
July, 1887	526.5	434.2	—167.7	44.2	209.3
Sums	6,218.8	6,157.9	4,500.7	4,479.9	5,339.2
Means	21.5	21.6	16.1	16.6	18.9

*7 a. m.

TABLE C.—*Daily observations with hourly, daily, monthly, and annual means, New Haven, Conn., August* 1, 1886, *to July* 31, 1887—Continued.

SUMMARY MEAN POTENTIAL AT NEW HAVEN—Continued.

[From actual readings.]

Months.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.
August, 1886	10.1	13.3	8.8	12.0	11.0
September, 1886	23.2	14.3	17.6	14.2	17.3
October, 1886	10.8	15.5	17.2	12.3	14.0
November, 1886	20.8	20.5	19.4	18.6	19.8
December, 1886	78.2	59.4	36.7	37.6	53.0
January, 1887	28.2	17.7	17.0	23.6	21.6
February, 1887	6.2	28.4	22.5	16.4	18.4
March, 1887	6.7	18.0	20.3	22.8	17.0
April, 1887	*22.3	16.5	11.7	21.2	17.9
May, 1887	17.6	12.3	11.9	8.5	12.6
June, 1887	11.2	21.7	14.3	3.5	12.7
July, 1887	20.2	16.7	— 6.5	1.9	8.1
Sums	255.5	254.3	190.9	192.6	223.4
Means	21.3	21.2	15.9	16.0	18.6

[Relative values.]

August, 1886	.92	1.21	.80	1.09	1.00
September, 1886	1.34	.83	1.02	.82	1.00
October, 1886	.77	1.11	1.23	.88	1.00
November, 1886	1.05	1.04	.98	.94	1.00
December, 1886	1.48	1.12	.69	.71	1.00
January, 1887	1.31	.82	.79	1.09	1.00
February, 1887	.34	1.54	1.22	.89	1.00
March, 1887	.39	1.06	1.19	1.34	1.00
April, 1887	*1.25	.92	.65	1.18	1.00
May, 1887	1.40	.98	.94	.68	1.00
June, 1887	.88	1.71	1.13	.28	1.00
July, 1887	2.49	2.06	— .80	.23	1.00
Sums	13.62	14.40	9.84	10.13	12.00
Means	1.14	1.20	.82	.84	1.00

* 7 a. m.

TABLE D.—*Potential on clear and fair days, Terre Haute, Ind., April* 1, 1887, *to August* 31, 1888.

Date.	9 a. m	10 a. m.	11 a. m.	12 m.	1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	Means.	Remarks.
April 5	175	325	400	200	200	220	150	145	205	120	214	N. fr., fair.
April 7	235	280	160	150	150	150	150	155	150	145	172	SE. lt., clear.
April 8	220	350	310	200	190	225	330	250	140	140	236	Do.
April 9	250	280	210	130	155	200	160	150	135	.....	186	SW. lt., clear.
April 11	130	180	310	140	155	150	145	200	240	300	195	Do.
April 12	95	95	320	75	130	150	185	130	320	400	190	SW. lt., fair.
April 19	270	235	205	135	275	270	260	200	235	235	232	SW. lt., clear.
April 25	214	173	188	204	219	263	307	250	200	146	216	Var. lt., fair.
April 30	220	266	253	200	146	137	145	167	73	115	172	SE. fr., fair.
May 4	134	167	167	156	146	156	167	153	140	130	152	E. fr., fair.
Sums	1,943	2,351	2,523	1,590	1,766	1,921	1,999	1,800	1,838	1,731	1,965	
Means	194	235	252	159	177	192	200	180	184	192	197	
May 7	120	200	180	150	140	180	180	120	100	70	144	SE. lt., fair.
May 9	80	50	90	100	90	80	70	50	60	60	73	S. lt., clear.
May 10	120	80	80	80	80	80	80	80	50	.....	81	E. lt., fair.
May 12	180	167	153	140	140	170	200	170	140	140	160	S. lt., fair.
May 13	140	140	140	160	180	140	100	120	140	.....	140	SE. lt., clear.
May 16	110	110	100	150	150	130	100	140	90	90	117	SE. lt., fair.
May 18	250	220	180	180	140	130	120	130	125	120	160	Do.
May 19	180	190	180	170	180	130	80	105	130	.....	149	E. lt., clear.
June 3	170	110	140	170	200	150	100	130	170	.....	149	SW. lt., fair.
June 8	150	120	120	100	100	120	150	150	150	130	129	SW. fr., clear.
Sums	1,500	1,387	1,363	1,400	1,400	1,310	1,180	1,195	1,155	610	1,302	
Means	150	139	136	140	140	131	118	120	116	102	130	
June 11	120	135	150	135	120	135	150	225	150	105	142	SE. fr., clear.
June 13	135	200	225	115	100	110	120	110	100	90	130	SE. lt., clear.
June 15	225	135	120	105	105	105	105	150	195	100	134	W. lt., clear.
June 18	225	150	150	105	150	130	120	120	120	.....	141	N. fr., clear.
June 21	180	190	195	172	150	150	150	140	130	120	158	W. fr., fair.
June 24	120	120	120	120	30	105	180	135	90	30	105	Do.
June 27	165	150	120	120	120	75	75	75	75	75	105	E. fr., clear.
June 28	150	140	130	120	130	140	150	135	120	130	134	E. fr., fair.
June 29	225	205	180	190	180	165	150	150	150	112	171	SE. fr., fair.
July 11	110	110	120	120	120	140	150	130	100	.....	122	Var. lt., clear.
Sums	1,655	1,535	1,510	1,302	1,205	1,255	1,350	1,370	1,230	762	1,342	
Means	166	154	151	130	120	126	135	137	123	95	134	
July 12	100	110	120	100	100	90	80	80	90	90	96	Var. lt., clear.
July 15	60	85	110	90	80	140	200	150	100	100	112	W. fr., fair.
July 23	50	50	50	40	30	30	40	50	40	30	41	NE. fr., clear.
July 25	80	90	160	70	60	60	50	50	30	30	68	NE. lt., clear.
August 1	80	70	70	50	40	40	30	40	30	30	48	N. fr., clear.
August 6	160	130	200	120	100	110	120	130	200	100	137	NE. lt., clear.
August 8	50	70	70	80	90	120	180	70	30	50	81	E. lt., clear.
August 12	110	150	140	120	110	120	130	130	80	70	116	E. fr., fair.
August 13	130	110	120	90	90	100	100	100	100	90	103	E. lt., fair.
August 16	170	100	110	130	110	90	70	80	80	80	102	Do.
Sums	990	965	1,150	890	810	900	1,000	880	780	670	904	
Means	99	96	115	89	81	90	100	88	78	67	90	
August 24	130	150	130	130	100	100	120	130	100	130	122	N. fr., fair.
August 27	120	110	80	90	80	80	90	90	80	50	87	E. lt., fair.
August 29	70	50	70	120	110	110	110	180	100	.....	102	E. lt., clear.
August 31	110	80	100	120	80	105	130	100	80	60	96	Do.
September 15	30	60	110	110	110	150	70	50	30	60	78	NE. fr., clear.
September 21	50	50	50	55	60	90	130	160	100	60	80	SW. lt., fair.
September 24	130	150	140	125	100	120	130	105	110	120	123	E. lt., fair.
Sums	640	650	680	750	640	755	780	815	600	480	688	
Means	91	93	97	107	91	108	111	116	86	80	98	

SUMMARY.

(10)	1,943	2,351	2,523	1,590	1,766	1,921	1,999	1,800	1,838	1,731	1,965
(10)	1,500	1,387	1,363	1,400	1,400	1,310	1,180	1,195	1,155	610	1,302
(10)	1,655	1,535	1,510	1,302	1,205	1,255	1,350	1,370	1,230	762	1,342
(10)	990	965	1,150	890	810	900	1,000	880	780	670	904
(7)	640	650	680	750	640	755	780	815	600	480	688
Sums	6,728	6,888	7,226	5,932	5,821	6,141	6,309	6,060	5,603	4,253	6,201
Means	143	147	154	126	124	131	134	129	119	109	132

TABLE D.—*Potential on clear and fair days, Terre Haute, Ind., April* 1, 1887, *to August* 31, 1888—Continued.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1887.							
October 4	200	180	210	150	150	178	NW. br., clear, gale.
October 12	480	400	450	500	350	436	SW. fr., clear.
October 14	180	200	160	180	100	164	N. lt., clear.
October 15	220	200	200	220	220	212	SE. lt., clear.
October 19	280	280	300	50	150	212	Do.
October 25	200	400	400	200	350	310	N. lt., clear.
October 27	320	240	220	180	100	212	E. lt., clear.
November 11	200	200	210	220	180	202	N. lt., clear.
November 15	250	180	150	150	200	186	W. fr., fair.
November 28	200	150	300	200	300	230	Var. lt., clear.
Sums	2,530	2,430	2,600	2,050	2,100	2,342	
Means	253	243	260	205	210	234	
November 29	200	350	350	250	200	270	SE. fr., clear.
December 5	240	240	300	400	360	308	W. lt., clear.
December 6	440	360	300	300	280	336	S. fr., fair.
December 13	340	260	400	700	500	440	S. fr., clear.
December 22	300	400	440	400	420	392	SW. fr., clear.
December 24	660	360	360	300	400	416	NW. fr., clear.
1888.							
January 10	280	260	200	160	180	216	W. br., fair.
January 11	220	440	240	320	440	332	NW. fr., clear.
January 18	300	220	340	300	200	272	W. fr., clear.
January 19	660	760	630	700	700	690	S. br., clear.
Sums	3,640	3,650	3,560	3,830	3.680	3,672	
Means	364	365	356	383	368	367	
January 26	330	560	380	260	400	386	W. fr., clear.
January 27	260	400	380	360	270	334	N. br., clear.
February 6	540	580	300	560	360	468	S. fr., clear.
February 16	800	1,400	760	760	750	894	Do.
February 22	600	700	520	240	240	460	E. lt., clear.
March 8	350	320	160	150	280	252	Var. lt., clear.
March 15	220	240	180	150	180	194	S. lt., clear.
March 29	80	130	150	130	70	112	W. lt., clear.
March 30	70	50	50	70	110	70	S. fr., clear.
April 3	180	135	200	135	162	162	Clear.
Sums	3,430	4,515	3,080	2,815	2,822	3,332	
Means	343	452	308	282	282	333	
April 4	144	190	135	114	225	162	E. lt., fair.
April 6	144	150	135	150	90	134	N. lt., clear.
April 11	180	300	225	210	225	228	W. lt., clear.
April 13	300	140	120	225	200	197	S. fr., clear.
April 14	90	75	138	90	96	98	N. lt., clear.
April 25	70	100	60	45	35	62	S. fr., fair.
June 2	30	40	30	40	30	34	N. br., clear.
June 4	25	30	25	40	48	34	NE. fr., clear.
June 30	50	60	35	50	40	46	N. lt., clear.
July 2	100	120	80	100	80	96	E. lt., clear.
Sums	1,133	1,205	983	1,064	1,069	1,091	
Means	113	120	98	106	107	109	
July 3	60	100	100	40	100	80	S. fr., fair.
July 5	60	80	120	80	110	90	N. fr., fair.
July 11	240	256	240	120	150	201	SW. fr., clear.
July 12	160	170	180	280	144	187	Do.
July 13	146	160	100	84	66	111	E. br., clear.
July 19	105	125	115	80	80	101	NW. fr., fair.
July 20	105	100	85	95	110	99	E. lt., fair.
July 21	75	80	75	100	105	87	Do.
July 24	85	120	80	105	250	128	NE. lt., fair.
July 25	80	80	75	75	100	82	E. lt., fair.
Sums	1,116	1,271	1,170	1,059	1,215	1,166	
Means	117	127	117	106	122	117	

TABLE D.—*Potential on clear and fair days, Terre Haute, Ind., April* 1, 1887, *to August* 31, 1888—Continued.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1888.							
July 31	140	200	40	180	125	137	S. fr., fair, hazy.
August 10	100	120	90	95	110	103	E. lt., fair.
August 13	300	150	110	80	110	150	E. fr., fair.
August 18	200	160	200	120	250	186	N. lt., fair.
August 22	90	90	120	145	280	145	NE. fr., fair.
August 23	120	50	40	60	60	66	E. lt., clear.
August 24	80	100	100	100	120	100	S. lt., clear.
Sums	1,030	870	700	780	1,055	887	
Means	147	124	100	111	151	89	

SUMMARY.

(10)	2,530	2,430	2,600	2,050	2,100	2,342	
(10)	3,640	3,650	3,560	3,830	3,680	3,672	
(10)	3,430	4,515	3,080	2,815	2,822	3,332	
(10)	1,133	1,205	983	1,064	1,069	1,091	
(10)	1,116	1,271	1,170	1,059	1,215	1,166	
(7)	1,030	870	700	780	1,055	887	
Sums	12,879	13,941	12,093	11,598	11,941	12,490	
Means	226	245	212	203	209	221	

TABLE E.—*Potential on clear and fair days, Columbus, Ohio, July, 1886, to July, 1888.*

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1886.						
July 19	69	80	81	82	78	S. br., fair.
July 28	20	19	45	12	24	W. br., clear.
August 3	60	62	67	70	65	NW. fr., fair.
August 5	18	18	33	26	24	NW. br., fair.
August 6	24	13	12	6	14	SE. br., fair.
August 19	15	32	16	16	20	E. br., clear.
August 20	10	3	10	17	10	SE. br., fair.
August 27	21	17	18	21	19	W. br., clear.
August 31	31	41	36	37	36	NW. br., clear.
September 1	62	59	67	71	65	E. br., fair.
Sums	330	344	385	358	355	
Means	33	34	38	36	36	
September 2	70	76	67	70	71	E. br., fair.
September 3	59	49	50	49	52	SE. br., fair.
September 6	39	46	51	41	44	SE. br., clear.
September 7	34	41	29	43	37	SE. br., fair.
September 8	37	42	43	39	40	W. lt., fair.
September 9	29	32	27	29	29	W. br., fair.
September 20	42	48	55	50	49	N. fr., clear.
October 7	34	53	66	54	52	S. br., clear.
October 8	50	77	107	103	84	Do.
October 11	60	105	100	98	91	SW. br., clear.
Sums	454	569	595	576	549	
Means	45	57	60	58	55	
October 12	62	67	63	73	66	SW. br., clear.
October 13	63	73	63	60	65	Do.
October 18	7	15	16	14	13	S. br., clear.
October 19	18	17	20	19	18	SW. br., clear.
October 20	4	7	7	4	6	SW. fr., fair.
October 21	8	8	9	8	8	NW. fr., clear.
October 22	3	4	14	16	9	Do.
November 1	98	120	130	118	116	SW. fr., clear.
November 4	126	133	50	103	103	W. fr., fair.
November 5	42	51	46	38	44	S. fr., clear.
Sums	431	495	418	453	448	
Means	43	50	42	45	45	
November 8	96	106	120	118	110	W. fr., fair.
November 15	24	36	41	38	35	NW. fr., clear.
November 16	32	23	26	30	28	SE. fr., fair.
November 19	15	13	18	26	18	SW. fr., clear.
December 6	15	25	27	20	22	N. fr., clear.
December 8	30	55	57	32	44	S. br., clear.
December 10	49	30	18	8	26	Do.
December 16	27	56	73	38	48	W. fr., clear.
December 20	53	38	32	24	37	SW. fr., clear.
December 27	21	31	26	15	23	NW. fr., clear.
Sums	362	413	438	349	391	
Means	36	41	44	35	39	

SUMMARY.

(10)	330	344	385	358	355	
(10)	454	569	595	576	549	
(10)	431	495	418	453	448	
(10)	362	413	438	349	391	
Sums	1,577	1,821	1,836	1,736	1,743	
Means	39	46	46	43	44	

TABLE E.—*Potential on clear and fair days, Columbus, Ohio, July, 1886, to July, 1888*—Continued

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1887.						
January 3	111	206	146	65	132	SW. br., clear.
January 12	140	207	220	106	168	SW. br., fair.
March 1	294	318	228	246	272	W. fr., fair.
March 2	165	123	159	174	155	W. br., clear.
March 8	309	288	324	252	293	E. fr., clear.
March 17	243	240	240	207	232	N. fr., fair.
March 23	207	210	192	189	200	NW. fr., clear.
March 25	171	183	219	180	188	Do.
April 8	213	246	270	213	236	S. br., clear.
May 13	114	177	114	105	128	NE. fr., clear.
Sums	1,967	2,198	2,112	1,737	2,004	
Means	197	220	211	174	200	
May 19	147	180	114	141	146	S. br., clear.
May 20	102	192	129	105	132	SE. br., clear.
June 13	138	120	126	99	121	N. br., clear.
June 16	69	78	75	72	74	W. br., fair.
June 17	72	90	120	99	95	W. br., clear.
June 27	90	156	150	159	139	E. fr., clear.
June 28	177	159	162	153	163	Do.
June 29	183	144	147	222	174	SE. fr., fair.
July 1	90	108	135	147	120	SW. fr.,fair.
July 12	120	102	105	132	115	SW. br., clear.
Sums	1,188	1,329	1,263	1,329	1,279	
Means	119	133	126	133	128	
July 13	120	135	186	180	155	SW. br., fair.
July 15	105	135	156	126	130	SW. fr., fair.
July 26	75	106	135	120	109	NE. fr., fair.
July 27	90	138	126	84	110	Do.
July 28	150	165	186	168	167	NW. fr., fair.
July 29	135	261	255	150	200	N. br., clear.
August 3	27	54	21	156	64	N. fr., clear.
August 8	111	117	135	156	130	E. fr., clear.
August 9	90	66	57	72	71	SE. br., fair.
August 10	60	87	133	105	96	SW. br., clear.
Sums	963	1,264	1,390	1,317	1,232	
Means	96	126	139	132	123	
August 16	48	72	72	126	80	NE. br., fair.
August 19	72	114	51	108	86	NW. fr., fair.
August 30	45	144	75	69	83	SE. br., clear.
August 31	45	105	66	48	66	Do.
September 1	69	90	30	63	63	Do.
September 8	219	153	141	123	159	N. fr., clear.
September 14	99	69	84	147	100	S. br., clear.
September 15	132	81	81	69	91	N. br., fair.
September 20	189	102	165	45	125	SE. br., fair.
October 1	135	134	90	75	108	W. fr., fair.
Sums	1,053	1,064	855	873	961	
Means	105	106	86	87	96	
October 7	270	136	120	135	165	SW. br., clear.
October 12	180	165	150	42	134	NW. fr., fair.
October 13	159	165	159	120	151	W. fr., clear.
October 14	134	150	138	120	136	W. fr., fair.
October 19	228	243	144	120	184	E. fr., fair.
October 25	285	180	330	225	255	N. fr., clear.
November 1	162	225	129	120	159	E. br., clear.
November 2	69	168	150	270	164	S. br., clear.
November 3	72	165	231	180	162	Do.
November 4	192	105	15	30	86	W. fr., fair.
Sums	1,751	1,702	1,566	1,362	1,596	
Means	175	170	157	136	160	

TABLE E.—*Potential on clear and fair days, Columbus, Ohio, July, 1886, to July, 1888*—Continued.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1887.						
November 17	195	213	174	186	192	NW. fr., clear.
November 18	225	210	159	198	198	SW., clear.
November 28	189	315	288	255	262	NW., clear.
November 30	180	180	194	168	180	NE., fair.
December 1	466	555	501	435	489	E., clear.
December 5	96	153	69	180	123	NW., fair.
December 6	132	150	300	126	177	S., clear.
December 8	162	150	225	21	140	E., clear.
December 19	531	369	390	480	442	SE., fair.
December 22	234	174	186	210	201	W., fair.
Sums	2,410	2,469	2,486	2,259	2,404	
Means	241	247	249	226	240	
1888.						
January 2	195	192	186	246	205	W., fair.
January 10	177	84	210	150	155	Do.
January 11	183	150	90	90	128	NW., fair.
January 19	150	300	300	156	226	W., clear.
January 24	111	309	321	330	268	N., clear.
January 26	75	180	297	282	208	NW., fair.
February 6	630	339	363	354	340	S., clear.
February 13	396	645	609	339	497	Do.
February 15	54	156	120	360	172	N., clear.
February 16	612	615	390	384	500	S., clear.
Sums	2,259	2,970	2,886	2,691	2,699	
Means	226	297	289	269	270	
February 21	390	294	309	306	325	SW., fair.
February 22	449	330	315	252	336	E., clear.
February 23	291	429	270	210	300	SW. br., clear.
February 27	270	435	225	96	256	NW., fair.
March 7	120	210	300	288	230	NW., clear.
March 8	66	261	318	192	209	Do.
March 9	708	480	360	471	505	SE., fair.
March 13	240	297	315	120	243	NW., clear.
March 15	279	351	186	261	269	SW., clear.
March 19	375	144	189	246	238	Do.
Sums	3,188	3,231	2,787	2,442	2,911	
Means	319	323	279	244	291	
March 30	342	300	252	228	280	SW., clear.
April 2	222	183	120	60	146	NW., fair.
April 11	156	210	180	180	182	NW., clear.
April 12	150	180	165	162	164	NW., fair.
April 13	192	282	183	219	219	SW., fair.
April 17	294	369	360	165	297	NE., fair.
April 24	210	270	135	105	180	N., fair.
April 25	375	390	369	186	330	SE., clear.
April 26	144	135	198	195	168	W., clear.
April 27	90	135	138	120	121	SW. br., clear.
Sums	2,175	2,454	2,100	1,620	2,087	
Means	218	245	210	162	209	
May 2	156	255	201	240	213	E., fair.
May 3	240	75	189	135	160	SE., fair.
May 11	219	300	240	120	220	SE., clear.
May 16	120	150	54	135	115	NE., fair.
May 17	90	150	105	60	101	Do.
May 21	144	156	210	165	169	E., fair.
May 22	180	300	270	240	248	Do.
May 23	285	315	240	195	259	Do.
June 4	108	180	135	165	147	NE., clear.
June 5	180	165	120	150	154	SW., fair.
Sums	1,722	2,046	1,764	1,605	1,786	
Means	172	205	176	160	179	

TABLE E.—*Potential on clear and fair days, Columbus, Ohio, July, 1886, to July, 1888*—Continued.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1888.						
June 7	120	150	162	141	143	N., fair.
June 8	210	240	210	180	210	NE., fair.
June 12	150	150	150	156	152	NE., clear.
June 13	180	150	75	120	131	SW., fair.
June 15	120	114	75	60	92	Do.
June 18	135	105	123	112	119	NW., fair.
June 19	120	111	135	114	120	NE., clear.
June 26	75	105	150	120	112	NE., fair.
July 2	192	180	129	150	163	Do.
July 3	75	165	129	120	122	SE., clear.
Sums	1,377	1,470	1,338	1,273	1,364	
Means	138	147	134	127	136	
July 4	102	150	150	135	134	SW., fair.
July 10	90	120	120	90	105	N., clear.
July 11	105	117	135	120	119	W., clear.
July 12	120	135	150	135	135	Do.
July 16	120	135	144	129	132	SE., fair.
July 17	120	135	150	135	135	SW., fair.
July 19	162	159	66	78	116	SE., fair.
July 24	150	150	150	195	161	NW., clear.
July 25	195	150	105	90	135	SW., clear.
July 26	66	108	102	111	97	SW., fair.
Sums	1,210	1,359	1,272	1,218	1,269	
Means	121	136	127	122	127	

SUMMARY OF CLEAR AND FAIR DAYS, JANUARY, 1887, TO JULY, 1888.

Number of days.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
(10)	1,967	2,198	2,112	1,737	2,004	
(10)	1,188	1,329	1,263	1,329	1,279	
(10)	963	1,264	1,390	1,317	1,232	
(10)	1,053	1,064	855	873	961	
(10)	1,751	1,702	1,566	1,362	1,596	
(10)	2,410	2,469	2,486	2,259	2,404	
(10)	2,259	2,970	2,886	2,691	2,699	
(10)	3,188	3,231	2,787	2,442	2,911	
(10)	2,175	2,454	2,100	1,620	2,087	
(10)	1,722	2,046	1,764	1,605	1,786	
(10)	1,377	1,470	1,338	1,273	1,364	
(10)	1,210	1,359	1,272	1,218	1,269	
Sums (120)	21,263	23,556	21,819	19,726	21,592	
Means (1)	177	196	182	164	180	

TABLE F.—*Potential on clear and fair days, Ithaca, N. Y.*

JUNE, 1886, TO SEPTEMBER, 1887, INCLUSIVE.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1886.						
June 27	80	81	70	82	78	NW., clear.
June 28	50	58	77	84	67	N. lt., fair.
June 30	45	77	52	115	72	NW. lt., clear.
July 1	117	72	78	70	84	N. lt., clear.
July 3	43	67	78	108	74	Fair.
July 4	80	113	101	90	96	NW. lt., clear.
July 5	86	46	31	44	52	Do.
July 6	89	73	73	86	80	NW. lt., fair.
July 8	64	80	55	78	69	NW. br., clear.
July 11	63	79	76	68	72	NW. br., fair.
Sums	717	746	691	825	744	
Means	72	75	69	82	74	
July 12	136	44	65	63	77	NW. lt., clear.
July 22	90	120	150	183	136	Clear.
July 23	88	95	61	103	87	Do.
July 24	23	105	131	125	96	Var. lt., clear.
August 2	90	110	83	96	95	NW. br., fair.
August 4	80	75	50	76	70	W. lt., fair.
August 6	80	98	127	119	106	NW. lt., fair.
August 8	70	46	44	85	61	Clear.
August 9	45	109	103	118	94	SW. fr., clear.
August 10	65	87	119	116	97	S. fr., clear.
Sums	767	889	933	1,084	919	
Means	77	89	93	108	92	
August 12	158	158	176	136	157	NW. fr., fair.
August 15	68	71	101	143	96	NW. lt., clear.
August 18	101	108	105	126	110	Clear.
August 19	158	80	80	87	101	W. lt., clear.
August 21	49	94	104	136	96	SW. br., fair.
August 22	96	105	110	118	107	SW. fr., clear.
August 26	78	77	87	125	92	N. lt., clear.
August 27	92	87	103	146	107	Clear.
August 28	94	99	94	91	94	Do.
August 29	115	78	72	103	92	SW. fr., fair.
Sums	1,009	957	1,032	1,211	1,052	
Means	101	96	103	121	105	
September 1	68	77	104	107	89	NW. br., fair.
September 6	108	123	110	118	115	W. lt., clear.
September 7	85	115	109	86	99	W. fr., clear.
September 8	98	121	130	117	116	SW. fr., clear.
September 9	57	62	76	60	64	SW. fr., fair.
September 10	108	119	78	99	101	Do.
September 11	84	74	58	70	72	NW. fr., clear.
September 13	258	112	88	77	134	NW. br., fair.
September 17	56	41	36	73	52	W. br., fair.
September 18	40	31	44	79	48	Fair.
Sums	962	875	833	886	890	
Means	96	88	83	89	89	
September 30	118	111	135	140	126	W. br., clear.
October 3	101	96	89	100	96	N. lt., clear.
October 6	92	96	131	155	118	W. lt., fair.
October 8	80	165	159	134	134	W. lt., clear.
October 9	142	92	109	158	125	W. fr., clear.
October 10	198	169	143	126	159	W. lt., fair.
October 11	84	76	60	65	71	SW. fr., clear.
October 21	46	95	60	103	76	NW. br., fair.
October 22	150	168	170	177	166	W. fr., clear.
October 23	180	382	372	255	297	Do.
Sums	1,191	1,450	1,428	1,413	1,368	
Means	119	145	143	141	137	

TABLE F.—*Potential on clear and fair days, Ithaca, N. Y.*—Continued.

JUNE, 1886, TO SEPTEMBER 1887, INCLUSIVE—Continued.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1886.						
November 1	265	249	208	161	221	Clear.
November 4	187	104	154	118	141	NW. br., clear.
November 22	145	206	180	167	174	S. lt., clear.
1887.						
January 8	182	297	22	417	230	NW. lt., clear.
January 11	205	315	265	250	259	SE. fr., clear.
March 12	55	55	45	20	44	NW. fr., clear.
March 31	290	270	285	200	261	E. lt., clear.
April 2	127	177	43	67	104	N. lt., clear.
April 3	170	92	123	112	124	Fair.
April 8	217	250	200	140	202	Clear.
Sums	1,843	2,015	1,525	1,652	1,760	
Means	184	202	152	165	176	
April 20	157	217	180	95	162	SW. lt., clear.
May 13	99	143	115	110	117	Var. lt., clear.
June 11	99	82	101	88	92	SE. lt., fair.
June 12	143	44	47	47	70	NW. lt., clear.
June 14	115	148	148	11	106	Do.
June 15	44	115	126	93	94	SW. fr., clear.
June 20	146	132	93	77	112	NW. lt., fair.
June 23	115	137	123	93	117	S. fr., fair.
June 25	27	66	11	88	48	Fair.
June 26	22	88	82	88	70	NW. fr., fair.
Sums	967	1,172	1,026	790	988	
Means	97	117	103	79	99	
June 28	183	88	91	121	121	NW. fr., clear.
June 29	160	82	82	99	106	NW. lt., clear.
July 1	110	104	99	104	104	SW. lt., fair.
July 2	104	104	132	143	121	Do.
July 3	66	82	77	99	81	SE. lt., clear.
July 4	71	77	60	82	72	SW. br., fair.
July 7	45	60	60	65	58	W. fr., clear.
July 13	125	125	112	112	118	Var. lt., fair.
July 19	95	80	75	110	90	Fair.
July 27	75	70	85	80	78	NW. lt., clear.
Sums	1,034	872	873	1,015	949	
Means	103	87	87	102	95	
July 28	125	90	80	100	99	Var. lt., clear.
July 30	100	80	100	155	109	SW. fr., clear.
July 31	85	70	85	90	82	W. lt., clear.
August 7	70	70	65	60	66	NW. fr., clear.
August 8	125	75	115	110	106	Clear.
August 12	55	115	75	110	89	NW. fr., clear.
August 13	65	105	110	105	96	NW. lt., clear.
August 14	125	85	85	55	88	Clear.
August 25	135	100	150	125	128	NW. high, fair.
Sums	885	790	865	910	863	
Means	98	88	96	101	96	

SUMMARY.

(10)	717	746	691	825	744	
(10)	767	889	933	1,084	919	
(10)	1,009	957	1,032	1,211	1,052	
(10)	962	875	833	886	890	
(10)	1,191	1,450	1,428	1,413	1,368	
(10)	1,843	2,015	1,525	1,652	1,760	
(10)	967	1,172	1,026	790	988	
(10)	1,034	872	873	1,015	949	
(9)	885	790	865	910	863	
Sums (89)	9,374	9,766	9,206	9,786	9,533	
Means	105	110	103	110	107	

TABLE F.—*Potential on clear and fair days, Ithaca, N. Y.*—Continued.

OCTOBER, 1887, TO AUGUST, 1888, INCLUSIVE.

Date.	9 a.m.	11 a.m.	1 p.m.	3 p.m.	5 p.m.	Means.	Remarks.
1887.							
October 8	375	342	243	235	270	293	W. lt., fair.
October 15	546	400	362	308	398	403	W. lt., clear.
October 16	382	236	150	164	173	221	SW. fr., fair.
October 26	1,198	950	725	766	680	864	Var. lt., fair.
October 28	368	385	204	214	214	277	NW. lt., fair, hazy.
October 31	455	368	330	317	367	367	SW. lt., fair.
November 1	264	430	312	249	304	312	NW. br., clear.
November 2	434	435	300	315	343	365	N. lt., clear.
November 6	331	450	205	260	410	331	S. lt., clear.
November 9	391	443	335	340	330	368	SE. lt., fair.
Sums	4,744	4,439	3,166	3,168	3,489	3,801	
Means	474	444	317	317	349	380	
December 1	1,053	1,131	1,195	535	874	958	E. lt., clear.
December 6	590	380	149	256	440	363	Var. lt., clear.
December 13	300	560	800	680	791	626	Var. lt., fair.
December 14	760	880	970	780	640	806	SE. lt., clear.
1888.							
February 12	915	1,210	890	895	970	975	SE. lt., fair.
February 13	950	915	815	650	500	766	S. lt., fair.
February 16	330	380	520	620	260	422	W. lt., fair.
February 23	640	500	550	408	370	494	S. fr., fair.
February 24	320	400	360	600	430	422	SE. fr., fair.
March 9	610	600	850	750	760	714	N. fr., fair.
Sums	6,468	6,956	7,099	6,174	6,035	6,546	
Means	647	696	710	617	604	655	
March 18	909	870	830	740	601	790	N. lt., clear.
March 19	877	1,250	880	810	1,030	969	SE. br., fair.
March 25	316	537	239	478	491	412	SE. lt., fair,
April 9	312	164	148	219	255	220	SE. lt., clear.
April 29	111	200	145	125	208	158	NW. fr., fair.
May 3	260	445	280	235	203	285	S. fr., fair.
May 22	250	389	355	325	514	367	Do.
May 23	406	360	331	141	156	279	SE. fr., fair.
June 3	164	190	140	190	265	190	NW. fr., clear.
June 5	250	300	350	280	180	272	SW. fr., clear, hazy,
Sums	3,855	4,705	3,698	3,543	3,903	3,942	
Means	386	470	370	354	390	394	
June 8	280	149	210	270	110	204	NW. lt., clear.
June 9	275	230	280	250	230	253	S. fr., clear.
June 17	95	126	95	90	120	105	NW. fr., clear.
June 18	130	350	145	220	282	225	NW. fr., fair.
June 19	230	295	220	260	310	263	NW. lt., clear.
June 20	210	180	150	280	280	220	NW. lt., fair.
June 21	140	186	124	160	241	170	SE. lt., fair.
June 22	210	240	180	210	261	220	W. lt., fair.
July 1	100	103	60	140	162	113	NW. fr., fair.
July 2	178	148	128	210	115	156	N. lt., fair.
Sums	1,848	2,007	1,592	2,090	2,111	1,929	
Means	185	201	159	209	211	193	
July 3	205	205	197	200	227	207	S. fr., fair.
July 4	215	220	160	168	160	185	SW. fr., fair.
July 6	330	350	230	210	295	283	NW. lt., clear.
July 7	240	249	264	218	214	237	NW. fr., fair, haze.
July 12	578	560	562	380	262	468	W. fr., fair, haze.
July 14	491	358	222	232	195	300	NW. fr., fair.
July 16	110	200	150	150	170	156	NW. fr., clear.
July 21	242	110	107	120	185	153	Do.
July 22	160	180	215	145	90	158	NW. lt., clear.
July 28	127	120	90	40	80	91	NW. fr., fair.
Sums	2,698	2,552	2,197	1,863	1,878	2,238	
Means	270	255	220	186	188	224	

TABLE F.—*Potential on clear and fair days, Ithaca, N. Y.*—Continued.

OCTOBER, 1887, TO AUGUST, 1888, INCLUSIVE—Continued.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1888.							
July 29	110	130	100	110	170	124	NW. fr., fair.
July 30	100	145	125	150	270	158	SE. lt., fair, haze.
August 1	350	100	100	190	210	190	NW. fr., clear, haze.
August 3	160	140	120	200	110	146	SW. fr., fair.
August 6	110	120	170	200	210	162	W. lt., fair.
August 7	160	190	190	140	150	166	NW. fr., fair.
August 8	190	140	140	160	150	156	SW. fr., fair.
August 9	150	155	200	255	220	196	NW. fr., fair.
August 10	210	200	225	230	165	206	NW. fr., clear.
August 19	215	220	200	230	270	227	S. fr., clear.
Sums	1,755	1,540	1,570	1,865	1,925	1,731	
Means	176	154	157	186	192	173	
August 28	280	270	220	230	370	274	N. fr., fair.
August 29	290	310	230	280	395	301	NW. fr., fair.
August 30	390	395	240	360	340	345	SW. fr., fair.
Sums	960	975	690	870	1,105	920	
Means	96	98	69	87	110	92	

SUMMARY.

Number of days.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.
(10)	4,744	4,439	3,166	3,168	3,489	3,801
(10)	6,468	6,956	7,099	6,174	6,035	6,546
(10)	3,855	4,705	3,698	3,543	3,903	3,942
(10)	1,848	2,007	1,592	2,090	2,111	1,929
(10)	2,698	2,552	2,197	1,863	1,878	2,238
(10)	1,755	1,540	1,570	1,865	1,925	1,731
(3)	960	975	690	870	1,105	920
Sums	22,328	23,174	20,012	19,573	20,446	21,107
Means	355	368	318	311	325	335

TABLE G.—*Potential on Clear and Fair Days,*

[Hourly observations from

Date.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1885.												
January 2	100	125	100	100	100	100	50	25	25	25	40	30
January 3	75	75	75	75	75	150	150	50	25	100	100	125
January 7	40	40	40	40	40	0	10	50	75	75	75	75
January 8	140	150	150	140	125	125	150	200	150	60	50	30
January 9	75	150	200	175	150	150	150	100	150	200	150	150
January 13	150	175	140	140	175	250	200	175	150	150	150	150
January 14	60	50	50	50	60	75	30	40	75	100	50	20
January 20	150	120	100	90	100	100	120	125	150	100	100	75
January 26	30	25	25	25	40	50	100	50	50	10	30	75
January 27	40	20	40	40	40	50	75	150	125	100	75	75
January 30	125	175	150	150	125	160	250	75	60	50	40	40
January 31	100	100	110	100	100	100	100	150	175	150	160	150
February 22	100	100	100	100	110	110	90	75	60	40	30	30
February 24	100	100	125	125	125	200	175	100	75	40	25	25
March 3	100	120	130	160	150	160	175	200	190	150	150	130
March 5	30	60	125	90	100	125	150	110	40	30	10	0
March 30	110	75	75	75	60	75	—5	125	175	125	150	100
April 9	40	50	60	50	50	50	50	50	100	85	100	75
April 18	35	35	55	50	40	50	15	50	85	70	50	50
April 19	50	60	60	65	60	70	60	60	60	75	90	90
April 20	135	140	115	100	50	60	190	140	150	100	200	120
May 10	120	80	90	100	105	110	100	110	95	110	115	110
June 6	75	70	70	70	70	65	65	70	55	55	60	60
June 12	60	60	60	45	50	50	50	35	50	50	50	100
June 20	65	60	60	50	60	50	0	100	100	110	130	100
June 29	95	95	100	100	100	85	100	100	100	85	100	.....
July 1	50	60	55	55	90	100	100	110	95	50	60	50
July 4	50	60	60	65	90	70	5	30	45	50	50	50
July 11	140	140	135	130	135	150	130	110	110	105	110	110
July 12	50	25	40	40	30	40	45	60	50	55	50	50
Sums	2,490	2,595	2,695	2,595	2,605	2,930	2,880	2,825	2,845	2,505	2,550	2,245
Means	83	86	90	86	87	98	96	94	95	84	85	77
July 15	25	45	25	40	70	100	0	50	50	25	40	50
July 16	55	60	65	65	90	90	100	70	60	40	40	30
July 17	50	60	60	60	65	80	45	110	50	60	60	50
July 23	60	40	20	60	50	0	10	60	100	130	100	70
August 5	30	25	30	20	50	100	50	50	35	30	30	30
August 6	50	45	40	50	70	100	20	20	50	70	60	70
August 9	50	50	60	70	80	100	110	90	90	85	85	100
August 11	85	85	70	40	60	80	100	70	80	80	100	70
August 16	45	40	50	40	30	30	50	60	50	50	50	50
August 28	80	70	45	40	55	60	80	50	75	90	100	100
September 1	60	65	50	60	50	50	60	70	60	55	50	50
September 2	25	30	30	30	40	50	55	65	50	50	50	25
September 3	60	70	60	100	60	70	0	70	60	30	15	0
September 14	60	100	90	70	70	80	90	50	90	100	110	120
September 15	30	40	45	50	50	60	70	70	80	85	75	95
September 16	40	40	50	50	70	110	90	60	70	70	60	60
September 17	50	55	50	55	55	100	50	60	80	30	75	60
September 20	50	50	40	35	35	40	30	35	25	25	25	25
September 24	50	50	45	70	50	75	85	50	40	35	20	15
September 26	55	70	75	40	50	60	20	35	—20	70	80	100
September 27	55	70	60	60	60	50	50	60	45	30	40	50
September 28	40	50	50	50	50	20	25	20	30	50	80	80
September 29	25	40	60	55	60	60	60	80	50	60	100	100
October 5	90	100	100	110	105	125	150	50	115	130	125	125
October 7	65	50	50	55	55	75	100	110	90	75	80	75
October 11	100	110	95	95	90	100	100	140	150	150	25	150
October 15	30	30	50	40	50	75	75	90	110	90	75	75
October 16	65	50	50	75	75	105	100	100	175	160	175	150
October 17	75	60	100	50	60	60	65	30	60	60	100	150
October 18	30	75	95	60	65	125	125	130	95	80	60	60
Sums	1,585	1,725	1,710	1,695	1,820	2,230	1,965	2,005	2,095	2,095	2,085	2,185
Means	53	58	57	56	61	74	66	67	70	70	70	73

Baltimore, Md., 1885, 1886, *and* 1887.

the photographic sheets.]

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
30	50	60	75	75	80	100	100	125	125	100	80	NW. br., clear.
100	150	150	125	100	100	125	125	125	100	100	90	SE. fr., fair.
75	75	75	75	90	100	100	90	75	100	125	125	W. br., fair.
75	100	100	100	90	150	150	100	125	75	50	50	SW. fr., fair.
150	100	100	100	100	50	50	50	40	0	—10	0	SW. fr., clear, fog.
65	80	65	65	65	75	80	75	100	65	75	50	NW.fr., fair.
125	160	100	125	100	75	75	60	50	50	80	60	E. fr., clear.
50	60	50	50	60	60	80	80	100	100	100	75	NW. fr., fair.
75	50	50	80	75	50	60	50	75	60	50	30	NW. br., clear.
100	130	100	100	100	50	75	100	90	90	100	150	NW. br., fair.
200	175	165	165	125	150	50	50	100	75	50	120	W. fr., fair.
140	130	150	150	100	50	50	75	75	75	60	0	NE. lt., fair.
150	125	100	75	75	50	60	50	50	60	75	75	NW. fr., clear
100	100	110	110	125	90	75	80	90	75	100	100	Do.
30	60	60	60	60	60	50	50	40	50	75	100	S. fr., fair.
30	25	10	25	0	25	10	10	10	30	50	25	N. fr., fair.
50	100	75	100	100	50	125	75	75	30	20	30	W. lt., fair.
80	75	50	50	40	50	50	50	50	60	50	50	NW. fr., clear.
50	85	95	75	50	35	35	45	60	60	50	50	Var. lt., fair.
100	150	200	150	160	140	160	150	140	100	150	120	E. fr., clear.
200	170	150	160	200	50	25	50	15	40	50	50	SE. fr., clear.
15	100	100	100	100	85	70	50	50	40	40	40	NW. fr., fair.
50	75	50	50	100	80	100	90	100	100	95	75	SE. fr., clear.
100	150	130	110	100	100	50	110	95	70	70	70	S. fr., clear.
60	100	75	60	60	25	50	50	60	55	50	50	W. lt., fair.
.....	50	70	75	60	75	75	85	80	70	60	70	W. fr., fair.
40	35	40	40	25	35	20	25	30	40	40	40	NW. fr., fair.
40	50	65	80	80	90	110	95	90	65	45	25	SW. fr., clear.
100	40	25	40	60	0	0	50	15	40	40	40	Var. fr., fair.
50	50	50	60	60	50	30	60	70	50	50	55	NE. fr., clear.
2,430	2,800	2,620	2,630	2,535	2,080	2,110	2,130	2,000	1,950	1,990	1,895	
84	93	87	88	84	69	70	71	67	65	66	63	
50	75	100	140	90	50	50	50	70	70	50	100	Var. fr., clear.
50	65	65	60	50	55	40	50	50	0	50	25	S. lt., clear.
45	25	50	80	80	50	30	70	30	50	100	25	S. lt., fair.
50	75	100	115	100	60	100	60	65	80	60	85	SE. lt., fair.
50	45	45	45	55	50	50	45	55	20	50	25	NW. fr., clear.
65	50	55	55	20	15	10	15	70	100	65	100	N. fr., clear.
100	100	110	135	160	125	150	130	130	170	60	35	NW. fr., fair.
60	100	125	125	135	155	120	100	70	70	60	85	SE. fr., fair.
50	50	45	50	55	100	80	95	90	100	100	100	N. fr., clear.
60	70	60	60	65	70	80	50	80	50	50	50	NW. fr., fair.
40	50	45	50	45	50	50	40	45	40	30	20	NW. fr., clear.
50	25	40	25	15	50	30	60	25	50	40	70	NW. lt., clear.
45	100	80	50	60	60	50	70	40	60	70	60	S. lt., clear.
100	110	50	5	100	100	20	40	10	10	10	20	S. fr., fair.
70	75	70	55	60	70	90	70	50	40	40	30	W. lt., clear.
50	55	60	5	70	20	40	50	50	70	60	55	NW. fr., clear.
100	120	50	100	130	135	100	70	60	60	80	50	NW. lt., clear.
35	50	50	50	70	75	60	40	30	50	20	30	NE. lt., fair.
5	5	15	25	50	50	50	60	40	25	25	50	SW. fr., clear.
110	110	120	100	110	90	50	70	20	25	40	40	Var. lt., clear.
100	90	130	90	100	100	10	50	50	50	70	50	Var. lt., fair.
70	70	100	100	70	40	10	40	40	50	45	40	Do.
70	50	50	50	100	130	100	70	70	25	30	40	Var. lt., clear.
65	60	75	70	60	75	100	110	75	85	90	60	SW. lt., fair.
70	75	75	80	80	75	75	60	40	60	60	50	Var. lt., fair.
125	125	140	65	95	125	100	90	85	65	100	75	Var. lt., fair.
50	60	75	60	75	60	60	75	60	60	60	80	NW. fr., cloudy.
150	150	160	200	200	120	100	75	50	0	50	25	SE. fr., fair.
150	150	150	150	150	50	—25	30	110	30	60	50	Var. lt., fair.
.....	100	90	80	75	75	60	60	65	60	60	60	Do.
2,035	2,285	2,380	2,275	2,525	2,280	1,840	1,895	1,725	1,625	1,685	1,585	
70	76	79	76	84	76	61	63	58	54	56	53	

TABLE G.—*Potential on Clear and Fair Days,*

[Hourly observations from

Date.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1885.												
October 20	60	50	60	60	60	75	80	100	90	85	80	75
October 22	50	50	50	40	60	95	130	90	80	75	50	40
October 24	60	60	50	50	55	65	75	75	70	65	65	60
October 25	60	75	75	50	30	40	60	100	110	100	95	95
October 26	75	70	60	60	60	50	10	50	— 50	150	140	100
November 3	50	60	60	75	75	110	90	90	80	60	60	60
November 4	75	125	150	150	175	175	225	200	100	90	110	100
November 11	85	105	110	100	100	175	200	180	125	225	250	150
November 12	130	125	150	110	125	110	150	100	125	125	125	125
November 14	100	150	100	150	125	150	100	100	150	100	160	100
November 17	90	90	90	90	60	60	150	50	100	100	60	60
November 20	40	50	50	75	75	100	90	110	100	100	100	100
December 2	60	70	70	50	20	35	15	50	65	105	100	100
December 10	130	100	10	10	5	0	0	20	10	10	40	55
December 11	40	40	40	40	35	40	45	50	45	50	45	25
December 12	100	100	100	100	95	100	110	80	90	80	25	20
December 15	70	100	60	90	90	100	110	130	130	100	120	80
December 16	150	180	160	210	230	230	300	300	300	200	180	150
December 17	150	135	135	150	150	150	175	140	150	200	175	175
December 22	40	50	55	50	100	70	100	150	110	150	100	100
December 24	40	50	50	55	40	30	55	60	60	55	50	50
December 25	40	60	55	50	45	55	60	70	80	70	70	80
1886.												
January 1	50	65	60	70	60	80	200	180	140	150	120	100
January 2	100	40	60	70	70	100	50	50	140	120	100	110
January 7	50	65	60	60	70	85	80	110	70	70	70	70
February 16	45	60	60	50	65	100	120	150	100	70	70	.....
February 18	90	60	60	70	100	100	120	150	120	80	50	50
February 21	45	50	50	50	50	50	90	75	90	60	110	100
February 22	0	100	100	50	60	60	75	80	70	70	70	70
February 24	50	80	70	65	100	200	120	105	110	150	200	200
Sums	2,125	2,415	2,260	2,300	2,385	2,790	3,185	3,195	2,960	3060	2,990	2,600
Means	71	80	75	77	80	93	106	106	99	102	100	90
March 5	50	50	50	50	50	50	50	40	20	50	40	40
March 6	60	50	30	50	50	50	50	60	40	50	30	30
March 7	50	40	40	40	40	45	80	70	50	50	50	50
March 11	70	80	75	70	70	80	85	80	80	80	80	20
March 14	25	30	30	30	30	40	50	60	65	65	60	50
March 15	50	80	60	70	30	60	60	— 5	10	50	50	60
March 16	60	70	80	90	60	65	60	30	50	60	30	25
March 17	80	80	80	90	95	100	100	100	95	110	100	100
March 24	50	50	50	50	45	70	80	95	70	50	30	25
April 10	100	130	100	90	75	80	100	70	60	70	25	25
April 14	50	100	100	100	60	60	60	60	60	90	110	120
July 3	80	90	90	90	90	90	90	90	75	60	50	50
July 4	30	25	35	40	20	0	20	50	50	40	20	75
July 5	50	50	65	80	80	50	65	25	40	60	75	90
July 6	150	100	110	110	100	100	75	75	90	65	75	75
July 7	60	60	75	65	75	100	100	25	25	30	30	50
July 11	30	30	30	30	30	50	50	10	0	25	30	40
July 12	20	30	10	20	50	30	40	50	60	50	75	75
July 17	50	50	55	50	60	80	90	50	40	40	40	50
July 22	50	40	50	60	75	100	80	50	60	50	30	40
July 24	30	30	50	40	50	25	10	10	100	100	90	100
July 29	60	75	60	50	60	90	90	75	100	75	80	80
August 3	125	100	90	90	90	75	90	65	50	75	95	100
August 4	60	65	65	60	80	110	60	65	50	50	60	50
August 8	55	60	60	60	60	65	70	75	50	50	50	50
August 12	50	55	20	45	50	55	50	50	35	30	30	30
August 13	50	5	50	65	30	45	— 5	20	70	60	55	60
August 15	25	30	30	30	30	50	50	55	70	70	75	.....
August 19	120	140	125	120	135	140	140	130	120	110	90	.....
August 21	70	70	55	60	65	45	45	50	55	45	40	55
Sums	1,810	1,865	1,820	1,895	1,835	2,000	1,985	1,680	1,740	1,810	1,695	1,615
Means	60	62	61	63	61	67	66	56	58	60	57	58

Baltimore, Md., 1885, 1886, *and* 1887—Continued.

the photographic sheets.]

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
75	75	60	65	60	60	50	50	50	40	40	50	SE. fr., fair.
50	60	60	60	75	80	100	110	100	75	50	50	NW. fr., clear.
50	50	60	60	60	50	50	90	65	60	75	60	N. lt., fair.
90	75	50	90	95	80	75	30	0	50	65	50	Var. lt., clear.
110	150	150	125	100	75	65	55	65	60	60	50	N. lt., clear.
50	50	60	65	60	75	90	80	75	75	80	80	W. br., fair.
100	125	100	125	125	110	150	125	125	100	105	110	W. fr., fair
250	125	125	100	125	125	150	125	175	250	200	150	Do.
125	130	125	110	120	100	90	80	105	75	75	75	SW. lt., fair.
100	150	90	160	150	75	125	100	110	65	60	55	Var. lt., fair.
60	30	50	50	75	100	100	95	100	100	95	90	N. lt., fair.
100	100	100	100	125	100	100	75	50	—25	—20	20	N. lt., clear.
100	100	85	70	80	95	100	120	100	85	75	60	Do.
50	60	60	70	75	75	90	60	50	55	50	40	Var. lt., fair.
50	65	70	50	55	60	50	50	50	50	75	90	NW. lt., fair.
25	90	150	120	180	90	100	130	130	100	120	100	NE. lt., clear.
200	180	200	175	200	300	70	90	75	150	150	150	Var. lt., fair.
150	200	200	150	250	170	150	125	80	30	30	30	E. lt., fair.
130	110	160	170	100	150	150	145	160	150	150	145	NW. br., fair.
100	50	75	80	75	150	200	160	150	20	20	100	W. fr., fair.
50	50	75	70	50	50	50	30	50	70	40	50	NW. fr., fair.
70	80	95	50	50	100	80	50	30	40	25	10	NE. fr., fair.
90	90	100	100	120	100	160	140	100	40	100	100	W. lt., clear.
80	120	200	190	70	60	70	80	80	90	90	90	E. lt., clear.
70	80	80	80	85	70	80	80	80	85	80	75	NW. fr., clear.
.....	80	80	85	85	60	50	80	60	65	65	90	NW. br., fair.
45	40	40	35	20	100	80	70	80	60	35	40	SW. fr., clear.
.....	100	110	70	85	120	100	100	150	200	130	130	SW, fr., fair.
70	70	80	70	60	85	160	120	150	100	60	85	NW. br., clear.
200	200	200	200	200	220	200	140	110	60	60	60	SE. lt., fair.
2,640	2,885	3,090	2,945	3,010	3,085	3,080	2,785	2,705	2,375	2,240	2,285	
94	96	103	98	100	103	103	93	90	79	75	76	
40	45	50	50	50	50	50	75	60	100	110	90	NW. fr., fair.
40	40	40	45	40	40	80	100	10	80	80	60	NW. fr., clear.
.....	60	60	100	110	150	110	150	100	100	70	70	N. lt., fair.
70	75	60	70	80	90	100	150	100	70	20	10	NW. fr., clear
.....	40	60	50	100	70	80	80	60	70	70	60	SW. lt., clear.
45	50	50	50	150	10	60	60	100	90	60	60	Do.
0	—50	0	20	60	50	60	60	50	55	60	70	SW. fr., clear.
100	100	100	110	120	80	100	75	75	60	0	—10	NW. fr., clear.
50	50	55	65	65	60	60	80	95	150	150	100	NW. br., fair.
.....	140	120	130	105	70	50	50	50	50	5	10	S. lt., fair.
120	150	200	200	150	200	200	80	100	75	60	80	E. lt., clear.
30	25	10	0	25	30	50	70	60	10	125	60	N. lt., fair.
40	40	50	50	40	65	35	50	60	50	50	75	Var. lt., fair.
75	60	40	60	75	75	65	60	75	25	20	75	SW. lt., clear.
65	50	65	110	150	130	65	75	100	65	65	60	E. lt., clear.
50	50	50	50	30	20	50	100	65	40	40	25	SW. fr., clear.
0	40	50	20	30	35	30	50	75	30	30	20	N. lt., clear.
50	60	40	75	50	60	30	50	110	40	50	50	E, lt., clear.
50	75	110	100	200	150	110	90	110	90	80	60	Var. lt., clear.
30	30	40	25	30	30	40	30	30	30	30	30	W. lt. clear.
75	100	125	100	90	60	60	60	60	50	50	50	E. lt., clear.
100	60	100	90	100	100	100	75	80	60	60	60	Do.
60	75	65	75	75	75	75	65	60	60	65	60	NW. fr., clear.
50	60	65	75	60	60	80	75	60	50	10	0	Do.
.....	50	75	85	70	70	60	115	65	65	50	55	NW. lt., clear.
30	60	50	45	85	85	45	100	65	60	65	50	W. fr., fair.
60	60	85	140	100	70	70	60	40	40	50	55	S. lt , fair.
.....	40	55	75	55	55	60	90	70	80	70	20	Var. lt., clear.
50	55	75	80	45	35	25	40	20	20	50	50	E. fr., clear.
45	65	60	60	25	40	65	70	70	70	45	40	E. fr., fair.
1,325	1,755	2,005	2,205	2,365	2,115	2,065	2,285	2,075	1,855	1,740	1,495	
53	58	67	74	79	70	69	76	69	62	58	50	

TABLE G.—*Potential on Clear and Fair Days,*

[Hourly observations from

Date.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1886.												
September 21	110	100	70	60	100	100	100	95	90	90	75	60
September 24	20	20	20	0	0	10	10	15	20	100	70	70
September 25	30	40	50	50	50	55	80	90	90	105	100	100
September 27	65	60	60	50	50	65	90	100	120	80	70	40
October 8	25	25	25	25	30	40	40	50	20	20	30	40
October 10	40	40	40	40	15	35	35	30	40	25	50	60
October 11	60	60	75	65	60	75	80	95	70	25	25	110
October 12	50	50	55	60	85	60	30	70	120	200	200	60
October 17	50	40	40	50	50	55	60	90	60	65	60	.....
October 18	120	150	140	120	105	110	100	100	110	110	70	70
October 20	10	10	10	10	10	0	0	15	30	60	65	65
October 22	70	100	100	60	80	100	140	130	100	60	60	70
October 23	100	110	90	110	150	100	120	110	90	60	50	60
October 24	40	50	60	40	50	40	35	40	50	50	60	.....
October 25	50	70	75	70	100	100	70	120	100	100	110	100
November 1	60	65	70	70	80	90	95	105	105	100	130	140
November 2	100	110	90	95	100	90	120	120	120	150	110	100
November 3	140	140	140	140	150	140	125	190	240	250	240	200
November 4	60	60	70	70	70	100	100	100	100	100	100	100
November 5	95	90	85	80	80	100	100	120	200	200	140	100
November 8	60	75	70	100	190	160	90	100	70	60	50	50
November 9	75	100	120	100	90	120	100	100	150	140	150	100
November 14	25	30	30	30	40	40	50	60	60	60	60	60
November 15	50	40	40	50	50	50	70	90	85	60	50	80
November 16	30	50	50	20	40	50	50	100	65	70	100	90
November 19	100	90	95	60	70	60	160	130	60	60	60	60
November 20	110	100	90	100	115	140	100	30	180	150	130	100
November 21	120	130	125	100	60	80	85	105	130	100	100	90
November 26	50	50	50	40	70	70	80	90	60	90	85	85
November 27	100	100	90	100	110	130	160	170	190	150	100	100
Sums	2,015	2,155	2,125	1,965	2,250	2,365	2,475	2,760	2,925	2,890	2,700	2,360
Means	67	72	71	66	75	79	82	92	98	96	90	84
November 28	140	100	120	120	100	80	75	80	140	130	125	130
November 29	90	120	120	120	105	110	115	150	150	150	160	140
December 9	100	100	150	100	100	100	70	80	120	110	150	.....
December 10	50	45	50	40	50	70	100	70	75	120	120	100
December 11	30	45	60	75	70	25	50	75	110	60	100	150
December 21	0	120	120	100	130	150	160	160	150	150	150	150
December 27	150	120	200	130	120	160	145	200	150	200	200	.....
1887.												
January 12	110	100	95	120	60	90	110	110	120	120	120	.....
January 22	20	110	25	0	30	20	20	50	50	60	80	50
January 31	100	120	130	110	110	130	100	100	110	110	120	140
February 9	60	45	60	50	50	50	50	55	55	35	30	60
February 17	30	40	50	70	70	100	100	80	80	60	60	50
February 22	80	80	80	80	100	100	110	100	90	110	100	.....
February 25	70	75	80	60	70	80	60	100	90	50	50	60
February 27	70	70	70	65	70	80	80	100	80	90	80	70
March 8	150	100	140	150	130	150	150	125	120	100	100	100
March 11	65	50	50	50	60	80	60	50	60	50	45	50
March 20	40	45	40	45	50	55	60	65	50	50	50	50
March 23	50	60	50	40	40	55	50	50	60	60	60	60
March 26	70	50	60	40	40	50	50	50	50	40	50	50
March 30	50	50	50	50	70	70	70	60	70	60	60	60
April 2	100	100	100	100	100	100	110	110	70	80	60	70
April 3	60	60	60	40	40	50	60	60	50	50	60	60
April 6	50	50	60	55	60	60	60	60	60	60	60	60
April 9	30	40	50	50	50	50	50	40	50	75	100	100
April 10	50	30	0	30	40	40	25	30	30	15	30	30
April 11	40	50	50	50	100	70	50	70	60	15	25	30
April 12	10	20	20	20	10	5	10	20	5	80	80	85
April 13	0	10	0	10	5	10	100	100	100	80	105	80
April 14	20	10	10	20	15	10	0	0	20	30	50	30
Sums	1,885	2,115	2,150	1,990	2,045	2,200	2,300	2,400	2,425	2,410	2,580	2,015
Means	63	70	72	66	68	73	77	80	81	80	86	78

Baltimore, Md., 1885, 1886, *and* 1887—Continued.

the photographic sheets.]

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
60	65	65	70	75	100	80	70	70	80	75	110	W. fr., clear.
100	100	150	100	100	80	100	50	50	20	10	40	SE. lt., clear.
120	170	180	85	50	30	30	40	60	70	60	60	S. lt., clear.
35	30	85	105	70	10	70	75	55	60	60	40	SW. lt., fair.
60	90	110	160	100	50	65	10	—30	0	10	20	Var. lt., clear.
.....	110	160	160	150	90	90	90	60	80	100	90	Do.
100	150	155	200	140	150	90	70	70	60	40	40	Do.
40	60	55	50	80	75	90	70	60	55	50	50	Do.
.....	120	130	140	120	95	130	240	100	90	140	120	NE. fr., fair.
65	90	105	250	200	160	80	80	65	70	70	70	Var. lt., clear.
100	120	120	90	80	50	50	50	40	30	40	40	Var. lt., fair.
65	60	55	55	70	110	130	60	25	50	60	50	W. fr., clear.
100	200	180	200	200	100	50	35	50	40	60	50	Var. lt., clear.
.....	70	90	100	90	90	70	60	60	60	70	100	E. fr., clear.
140	150	250	300	100	50	50	40	30	10	0	0	Var. lt., fair.
140	150	130	130	140	150	110	110	110	100	95	100	NW. fr., clear.
100	300	260	270	240	240	220	150	175	140	110	130	Var. lt., clear.
140	200	250	175	140	120	100	100	80	80	80	60	S. lt., fair.
100	120	125	120	170	120	150	120	80	100	100	100	NW. fr., fair.
120	150	200	150	80	60	65	60	65	90	80	40	Var. lt., fair.
50	65	40	55	50	50	60	70	100	90	100	60	NW. gale, clear.
100	95	150	180	120	230	160	180	190	95	75	75	NW. fr., clear.
.....	.....	75	60	60	65	65	50	50	40	30	50	NW. br., clear.
60	45	50	90	60	50	45	30	25	30	50	40	NW. fr., clear.
105	120	210	160	190	220	160	100	60	60	70	45	N. fr., fair.
45	60	60	50	55	50	75	60	70	90	100	105	W. br., clear.
100	75	60	50	65	80	80	80	90	110	110	100	SW. fr., fair.
.....	.....	140	150	105	150	100	100	100	95	90	100	Var. lt., fair.
100	100	120	120	120	100	110	100	110	120	160	165	NW. br., clear.
100	75	65	75	75	100	110	80	140	80	100	110	NW. fr., clear.
2,245	3,140	3,825	3,900	3,295	3,020	2,785	2,430	2,210	2,095	2,195	2,160	
90	112	128	130	110	107	93	81	74	70	73	72	
.....	.....	140	160	100	100	120	120	140	200	190	120	S. lt., clear.
100	130	150	110	110	190	175	190	85	50	50	100	SW. lt., fair.
.....	200	200	210	200	100	75	80	80	100	60	60	Var. lt., clear.
150	160	165	165	165	60	50	50	—50	0	0	40	Do.
160	240	200	160	130	110	140	100	100	100	90	100	Var lt., fair.
130	160	200	200	120	120	100	100	100	60	60	40	Var. lt., clear.
120	100	130	100	85	85	80	65	100	110	110	100	NW. fr., fair.
.....	160	200	130	175	200	250	300	300	150	210	240	SW. fr., fair.
100	130	150	105	110	80	20	50	60	70	95	60	Do.
150	140	115	105	110	80	80	70	80	150	140	100	E. fr, clear.
60	75	50	55	45	70	80	65	90	80	110	110	NW. fr., fair.
50	50	60	50	120	100	100	75	25	60	50	60	NW. lt., clear.
75	90	60	80	65	100	100	140	75	140	120	100	NW. fr., fair.
55	70	60	60	60	70	60	50	65	60	70	70	Var. lt., fair.
75	60	55	60	40	50	60	100	80	50	50	60	NW. gale, clear.
100	100	100	90	100	100	90	75	120	80	70	10	Var. lt., clear.
45	50	45	45	50	50	50	50	55	45	40	45	NW. br., clear.
.....	100	100	100	100	100	110	115	120	100	100	120	NW. fr., fair.
45	65	60	50	50	50	70	60	65	60	50	50	NW. br., fair.
50	50	50	65	50	25	50	50	40	20	30	40	N. fr., fair.
50	50	45	40	40	40	60	60	70	60	75	100	NW. fr., fair.
70	70	60	60	40	50	50	70	40	20	50	60	Do.
.....	60	60	65	80	80	80	50	50	50	50	25	SW. fr., clear.
60	60	50	45	40	30	40	100	100	50	50	—5	NW. br., fair.
100	120	150	140	90	50	50	30	30	50	40	50	Var. lt., clear.
.....	60	60	50	60	50	50	50	60	40	40	40	Do.
60	65	50	50	30	30	30	20	20	25	15	10	W. fr., clear.
65	110	120	100	90	75	80	50	50	25	25	25	E. lt., fair.
90	120	105	55	105	105	60	40	10	10	20	10	SE. lt., fair.
40	30	40	60	30	20	20	10	20	20	5	10	E. lt., fair.
2,000	2,885	3,030	2,760	2,590	2,370	2,380	2,385	2,190	2,035	2,075	1,950	
80	99	101	92	86	79	79	80	73	68	69	65	

TABLE G.—*Potential on Clear and Fair Days,*

[Hourly observations from

Date.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1887.												
April 20	70	90	80	60	80	70	90	90	90	70	70	70
April 21	50	50	50	40	50	50	50	50	100	105	110	150
April 24	40	40	40	50	50	50	60	60	60	60	60	.....
May 2	50	60	30	50	50	50	60	65	90	.....	100	100
May 22	20	20	40	40	30	50	50	60	60	60	60	60
May 23	90	90	90	90	90	90	60	50	70	70	70	70
June 4	50	50	50	50	60	70	70	50	40	40	40	40
June 11	50	50	50	10	60	60	50	60	40	—60	—60	—10
June 16	90	90	60	60	60	60	70	60	50	60	60	60
June 24	100	70	70	80	70	110	105	90	105	80	70	50
June 25	30	40	40	40	50	60	60	50	65	50	60	75
June 26	60	70	65	75	60	70	80	90	75	60	60	.....
June 28	75	75	70	50	65	80	80	60	60	60	40	60
June 30	50	50	40	40	60	50	70	50	50	80	80	80
July 1	100	110	90	90	100	80	100	140	130	125	160	.....
July 2	90	90	80	80	100	100	110	100	130	160	160	100
July 3	80	80	80	60	70	65	70	80	60	60	50	50
July 4	100	90	90	100	100	100	120	130	70	90	90	90
July 11	50	50	50	50	60	70	60	40	40	20	.....	30
July 12	40	40	50	60	70	90	60	40	60	50	50	50
July 13	50	50	50	50	40	50	30	40	50	50	50	50
July 14	40	40	50	50	55	60	50	50	50	50	60	60
Sums	1,375	1,395	1,315	1,275	1,430	1,535	1,555	1,505	1,545	1,340	1,440	1,235
Means	62	63	60	58	65	70	71	68	70	64	69	65

SUMMARY

	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.
1	83	86	90	86	87	98	96	94	95	84	85	77
2	58	58	57	56	61	74	66	67	70	70	70	73
3	71	80	75	77	80	93	106	106	99	102	100	90
4	60	62	61	63	61	67	66	56	58	60	57	58
5	67	72	71	66	75	79	82	92	98	96	90	84
6	63	70	72	66	68	73	77	80	81	80	86	78
7	62	63	60	58	65	70	71	68	70	64	69	65
Sums	459	491	486	472	497	554	564	563	571	556	557	525
Means	66	70	69	67	71	79	81	80	82	79	80	75

Baltimore, Md., 1885, 1886, *and* 1887—Continued.

the photographic sheets.]

1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Remarks.
60	120	100	140	120	80	70	90	130	100	100	50	N. lt., fair.
100	150	120	150	150	100	80	60	70	50	50	90	S. lt., clear.
.....	100	100	90	80	100	100	105	100	100	60	60	NW. fr., clear.
100	100	100	100	110	70	40	35	35	20	20	20	SE. fr., fair.
35	60	65	70	60	60	70	80	90	80	90	80	Var. lt., clear.
100	130	110	75	90	50	50	50	50	50	50	50	S. lt., fair.
30	70	50	50	20	40	100	100	100	100	70	70	NW. fr., fair.
—20	—50	20	50	50	50	60	40	60	40	30	50	E. br., clear.
50	70	80	60	50	45	60	50	—10	10	20	50	SW. lt., clear.
70	80	90	70	60	50	60	50	50	30	25	20	W. fr., fair.
70	100	105	110	80	60	75	100	30	60	60	60	N. fr., fair.
.....	70	50	60	70	70	25	60	30	30	20	10	Var. lt., fair.
40	150	80	150	160	140	80	120	90	80	80	60	Do.
70	90	90	95	80	80	80	80	120	100	100	90	S. lt., clear.
200	140	100	150	170	120	120	80	110	105	100	100	S. fr., clear.
100	200	180	150	90	90	80	75	90	80	70	80	Do.
.....	.....	.....	140	110	70	80	80	90	80	80	110	S. fr., fair.
100	105	60	80	90	90	90	70	60	70	60	60	SE. br., fair.
30	30	60	60	60	60	70	80	80	60	50	40	W. br., clear.
50	60	60	60	60	60	70	70	120	60	60	50	Do.
50	60	65	70	70	75	80	90	60	65	50	50	W. fr., fair.
50	55	45	10	10	10	30	30	30	40	40	30	Var. fr., clear.
1,285	1,890	1,730	1,990	1,840	1,570	1,570	1,595	1,585	1,410	1,285	1,280	
68	90	82	90	84	71	71	72	72	64	58	58	

OF MEANS.

1 p. m.	2 p. m.	3. p m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 mid.	Means.
84	93	87	88	84	69	70	71	67	65	66	63	82
70	76	79	76	84	76	61	63	58	54	56	53	66
94	96	103	98	100	103	103	93	90	79	75	76	91
53	58	67	74	79	70	69	76	69	62	58	50	63
90	112	128	130	110	107	93	81	74	70	73	72	88
80	99	101	92	86	79	79	80	73	68	69	65	78
68	90	82	90	84	71	71	72	72	64	58	58	69
539	624	647	648	627	575	546	536	503	462	455	437	537
77	89	92	93	90	82	78	77	72	66	65	62	77

TABLE H.—*Potential on clear and fair days, Washington, D. C., October, 1887, to August, 1888, inclusive.*

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1887.							
October 7	200	220	180	80	150	166	SE. lt., clear.
October 12	128	62	115	121	150	115	NW. fr., fair.
October 13	108	134	215	170	128	151	SW. lt., clear.
October 15	118	112	89	84	70	95	N. lt., clear.
October 17	157	248	138	244	224	202	S. lt., fair.
October 21	120	196	126	126	106	135	NW. br., fair.
October 22	200	161	190	200	224	195	NW. lt., clear.
November 1	142	157	156	141	114	142	N. fr., fair.
November 2	172	168	217	189	269	203	NW. lt., clear.
November 3	269	322	258	158	163	234	Var. lt., clear.
Sums	1,614	1,780	1,684	1,513	1,598	1,638	
Means	161	178	168	151	160	164	
November 5	112	160	145	124	83	125	NW. fr., clear.
November 12	96	72	96	72	79	83	NW. fr., fair.
November 29	172	168	162	176	182	172	N. lt., clear.
November 30	226	181	147	150	133	167	Do.
December 1	282	226	211	222	201	228	NE. lt., clear.
December 5	137	152	168	144	117	144	NW. fr., clear.
December 6	219	195	234	278	325	250	NW. lt., clear.
December 13	370	293	315	157	266	280	S. lt., clear, lt. haze.
December 16	157	168	178	168	202	175	NW. fr., clear.
December 19	202	206	168	183	277	207	NW. lt., fair.
Sums	1,973	1,821	1,824	1,674	1,865	1,831	
Means	197	182	182	167	186	183	
December 22	126	161	138	165	134	145	NW. fr., clear.
December 23	368	276	202	207	274	265	SW. lt., clear.
1888.							
January 3	176	195	174	121	155	164	W. lt., fair.
January 11	111	91	96	71	72	88	NW. fr., clear.
January 19	266	291	222	182	182	229	Do.
January 21	208	185	182	158	130	173	N. fr., clear.
January 24	198	252	195	238	219	220	Do.
January 28	168	150	148	166	141	155	NW. br., clear.
February 2	272	176	198	194	158	200	NW. lt., clear.
February 13	563	316	306	340	337	372	N. lt., clear.
Sums	2,456	2,093	1,861	1,842	1,802	2,011	
Means	246	209	186	184	180	201	
February 15	189	178	205	187	192	190	NW. br., clear.
February 16	317	408	398	320	235	336	S. lt., clear.
February 28	102	194	258	258	245	211	NW. br., clear.
March 3	200	176	160	163	117	163	Do.
March 6	282	102	187	291	245	221	NW. lt., clear.
March 7	357	171	208	180	197	223	NW. fr., clear.
March 8	202	147	202	149	136	167	NW. br., clear.
March 9	262	242	261	222	281	254	NW. fr., clear.
March 15	219	229	242	221	229	228	NW. lt., clear.
March 23	53	112	48	99	75	77	NW. fr., clear.
Sums	2,183	1,959	2,169	2,090	1,952	2,070	
Means	218	196	217	209	195	207	
March 30	408	277	146	138	165	227	S. lt., clear.
April 3	128	130	120	77	83	108	N. lt., clear.
April 4	88	56	126	37	133	88	S. lt., fair.
April 11	106	95	70	82	74	85	NW. br., clear.
April 13	120	117	90	94	107	106	NW. lt., fair.
April 17	122	84	124	54	108	98	S. lt., clear.
April 24	126	82	74	63	63	82	NW. br., fair.
April 25	122	110	115	114	130	118	NE. lt., clear.
April 26	138	149	131	125	152	139	S. lt., clear.
May 3	120	98	101	50	122	98	Do.
Sums	1,478	1,198	1,097	834	1,137	1,151	
Means	148	120	110	83	114	115	

TABLE H.—*Potential on clear and fair days, Washington, D. C., October* 1887, *to August*, 1888, *inclusive*—Continued.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1888.							
June 1	157	88	86	81	66	96	NW. fr., clear.
June 4	70	38	48	42	61	52	NW. lt., clear.
June 5	66	62	93	67	102	78	S. lt., clear.
June 6	72	58	66	62	84	68	Do.
June 7	48	30	53	53	58	48	NW. fr., fair.
June 9	56	42	47	61	90	59	S. fr., clear.
June 13	110	48	66	43	61	66	SE. fr., fair.
June 15	90	50	66	50	78	67	S. lt., fair.
June 19	46	32	78	58	70	57	E. lt., fair.
June 20	82	50	52	72	78	67	SE. lt., fair.
Sums	797	498	655	589	748	658	
Means	80	50	66	59	75	66	
June 21	34	38	38	47	31	38	SE. lt., fair.
June 22	101	80	66	91	84	84	NW. lt., fair.
June 25	48	46	61	67	48	54	NW. fr., clear.
July 3	125	141	104	102	147	124	SE. fr., fair.
July 6	127	118	116	127	195	137	NW. lt., clear.
July 11	64	147	136	123	111	116	W. fr., clear, lt. haze.
July 13	195	179	146	104	98	144	NW. fr., clear.
July 14	45	119	98	140	88	98	NW. fr., fair, lt. haze.
July 23	99	108	102	104	77	98	W. lt., clear.
July 25	157	169	105	94	137	132	S. lt., clear.
Sums	995	1,145	972	999	1,016	1,025	
Means	100	114	97	100	102	102	
July 26	98	94	74	119	153	108	SE. fr., clear.
August 2	52	94	76	78	80	76	NE. lt., clear, lt. haze.
August 7	105	115	70	73	69	86	NW. fr., clear.
August 10	119	106	45	74	67	82	N. lt., clear.
August 13	175	127	90	77	67	107	NW. fr., fair.
August 14	151	139	108	78	113	118	W. lt., fair.
August 15	162	73	134	73	90	106	Do.
August 16	15	46	39	66	67	47	S. lt., clear.
August 23	141	137	143	162	179	152	NW. fr., clear.
August 24	335	171	182	143	157	198	SW. lt , clear.
Sums	1,353	1,102	961	943	1,042	1,080	
Means	135	110	96	94	104	108	
August 25	200	172	161	160	147	168	W. lt., clear.
August 28	216	202	127	167	115	165	N. lt., clear.
August 29	105	108	158	209	84	133	S. fr., clear.
Sums	521	482	446	536	346	466	
Means	174	161	149	179	115	155	

SUMMARY.

Number of days.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.
(10)	1,614	1,780	1,684	1,513	1,598	1,638
(10)	1,973	1,821	1,824	1,674	1,865	1,831
(10)	2,456	2,093	1,861	1,842	1,802	2,011
(10)	2,183	1,959	2,169	2,090	1,952	2,070
(10)	1,478	1,198	1,097	834	1,137	1,151
(10)	797	498	655	589	748	658
(10)	995	1,145	972	999	1,016	1,025
(10)	1,353	1,102	961	943	1,042	1,080
(3)	521	482	446	536	346	466
Sums	13,370	12,078	11,669	11,020	11,506	11,930
Means	161	146	141	133	139	144

TABLE I.—*Potential on clear and fair days, Boston, Mass., July,* 1886, *to August,* 1888.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1886.						
July 5	8	14	8	6	9	Clear.
July 6	10	4	2	3	5	Do.
July 11	10	19	15	14	14	Do.
July 17	16	16	16	17	16	Do.
July 20	79	29	351	82	135	Do.
August 2	20	38	41	25	31	N. fr., fair.
August 8	55	58	160	141	105	Do.
August 10	18	87	30	37	43	W. br., clear.
August 13	110	126	96	6	84	E. fr., clear.
August 15	10	15	12	18	14	NW. fr., clear
Sums	336	406	731	349	456	
Means	34	41	73	35	46	
August 18	10	12	10	30	16	E, fr., clear.
August 19	5	20	5	5	9	SE. fr., clear.
August 20	12	45	20	105	46	Do.
August 21	4	5	40	10	15	S. fr., clear.
August 22	95	110	105	76	96	E. br., clear.
August 23	29	52	55	55	48	SW. fr., clear.
August 24	45	60	45	45	49	Do.
August 26	10	3	7	10	8	NW. fr., clear.
August 27	8	10	25	20	16	W. fr., clear.
August 28	28	28	50	40	36	SE. gen., clear.
Sums	246	345	362	396	339	
Means	25	34	36	40	34	
August 29	2	10	10	15	9	E. fr., clear.
September 1	160	162	196	225	186	NW. br., clear.
September 2	550	340	560	640	522	NE. fr., clear.
September 3	420	410	240	540	402	E. fr., clear.
September 7	40	56	50	55	50	W. fr., fair.
September 8	15	150	140	218	131	SW. fr., clear.
September 13	10	6	20	22	14	W. br., clear.
September 14	80	124	130	40	94	S. br., clear.
September 15	170	260	290	350	268	E. fr., fair.
September 19	150	192	181	191	178	SE. fr., fair.
Sums	1,597	1,710	1,817	2,296	1,854	
Means	160	171	182	230	185	
September 20	20	41	10	25	24	NW. br., clear.
September 21	10	31	25	34	22	W. br., clear.
September 22	17	33	20	22	23	NW. fr., clear.
September 29	19	24	22	27	23	NW., br., fair.
October 3	15	31	37	30	28	W. fr., clear.
October 6	7	37	51	50	36	N. fr., clear.
October 7	7	10	15	14	12	NE. br., clear.
October 8	31	34	37	36	34	NW. lt., clear.
October 9	31	30	29	32	30	W. br., clear.
October 10	20	15	23	14	18	SE. fr., clear.
Sums	177	286	269	284	250	
Means	18	29	27	28	25	
October 11	18	31	31	30	28	W. fr., clear.
October 12	64	10	33	22	32	W. fr., fair.
October 14	321	193	311	390	304	SE. fr., fair.
October 16	30	40	46	48	41	NW. br., clear.
October 18	9	12	12	13	12	E. br., fair.
October 19	4	35	40	37	29	E. fr., clear.
October 20	21	21	29	39	28	W. fr., clear.
October 22	112	40	70	61	71	SW. fr., clear.
October 23	14	20	31	26	23	SE. fr., clear.
October 24	92	119	190	182	146	E. fr., clear.
Sums	685	521	793	848	714	
Means	68	52	79	85	71	
November 2	50	571	192	16	207	N. fr., clear.
November 5	50	80	110	66	76	S. br., clear.
November 8	30	46	71	83	58	W. fr., clear.
November 9	144	130	120	135	132	Do.

TABLE I.—*Potential on clear and fair days, Boston, Mass., July, 1886, to August, 1888*—Continued.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1886.						
November 14	119	120	120	136	124	NW. high, clear.
November 16	111	58	29	30	57	NW. fr., fair.
November 19	132	241	225	210	202	W. br., fair.
November 21	150	226	240	256	218	W. fr., fair.
November 22	184	244	256	255	235	NW. fr., clear.
November 24	60	136	195	195	146	NW. high, clear.
Sums	1,030	1,852	1,558	1,382	1,455	
Means	103	185	156	138	146	
November 26	255	326	345	332	314	NW. br., clear.
November 27	392	335	325	376	357	W. fr., clear.
November 28	375	406	441	390	403	W. br., clear.
December 1	32	51	52	42	44	SW. high, fair.
December 2	75	69	69	64	69	W. high, fair.
December 3	120	166	210	135	158	W. br., clear.
December 8	130	156	94	126	126	Do.
December 9	105	142	147	135	132	NW. fr., clear.
December 10	225	105	195	145	168	W. br., fair.
December 11	63	87	100	74	81	W. br., clear.
Sums	1,772	1,843	1,978	1,819	1,852	
Means	177	184	198	182	185	
December 14	46	135	286	104	143	NW. br., fair.
December 17	208	222	225	255	228	W. br., clear.
December 19	67	95	113	94	92	W. fr., clear.
December 21	20	47	61	20	37	SW. high, clear.
December 25	191	414	229	153	247	NW. high, clear.
December 28	62	148	112	89	103	W. br., clear.
1887.						
January 2	32	71	61	55	55	W. high, fair.
January 3	63	170	140	106	120	NW. br., clear.
January 11	131	411	351	220	278	W. fr., clear.
January 12	103	160	171	122	139	SW. fr., clear.
Sums	923	1,873	1,749	1,218	1,442	
Means	92	187	175	122	144	
January 13	70	127	120	86	101	W. fr., clear.
January 16	122	191	191	170	168	NW. fr., clear.
January 18	42	90	99	80	78	W. br., clear.
January 21	47	63	42	23	44	NW. high, clear.
January 27	30	46	29	20	31	NW. fr., clear.
February 4	32	38	30	13	28	W. br., fair.
February 5	51	103	70	34	64	NW. fr., clear.
February 9	81	189	231	154	164	NW. br., clear.
February 12	63	88	132	65	87	Do.
February 13	29	179	142	39	97	Do.
Sums	567	1,114	1,086	684	862	
Means	57	111	109	68	86	
February 14	73	109	51	39	68	E. fr., clear.
February 16	1	13	16	5	9	Do.
February 17	8	12	13	13	12	W. fr., clear.
February 25	75	152	164	90	120	NW. high, clear.
February 28	55	50	40	29	44	Do.
March 3	62	110	100	85	89	N. br., clear.
March 8	39	129	110	70	87	NW. br., clear.
March 12	91	198	350	198	209	NW. br., fair.
March 14	31	90	65	32	54	NW. fr., clear.
March 25	15	42	31	22	28	W. high, clear.
Sums	450	905	940	583	720	
Means	45	90	94	58	72	
March 26	29	116	65	42	63	W. high, clear.
March 27	31	86	23	43	46	NW. br., fair.
March 30	56	192	220	160	157	W. high, clear.
March 31	17	21	21	15	18	W. fr., clear.
Sums	133	415	329	260	284	
Means	33	104	82	65	71	

TABLE I.—*Potential on clear and fair days, Boston, Mass., July, 1886, to August, 1888*—Continued.

SUMMARY.

Number of days.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.
(10)	336	406	731	349	456
(10)	246	345	362	396	339
(10)	1,597	1,710	1,817	2,296	1,854
(10)	177	286	269	284	250
(10)	685	521	793	848	718
(10)	1,030	1,852	1,558	1,382	1,455
(10)	1,772	1,843	1,978	1,819	1,852
(10)	923	1,873	1,749	1,218	1,442
(10)	567	1,114	1,086	684	862
(10)	450	905	940	583	720
(4)	133	415	329	260	284
Sums	7,916	11,270	11,612	10,119	10,235
Means	76	108	111	97	98

Date.	7 a. m.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	7 p. m.	11 p. m.	Means.	Remarks.
1887.									
April 10	11	.....	23	20	20	22	3	16	W. fr., clear.
April 14	16	.....	33	20	16	.....	.....	21	N. fr., fair.
April 20	21	.....	35	17	8	18	68	28	W. fr., clear.
April 22	16	.....	46	41	17	35	.....	31	SE. fr., clear.
May 2	43	.....	38	30	31	33	47	37	E. fr , fair.
May 5	69	.....	58	40	40	40	58	51	SE. fr., fair.
May 9	23	.....	31	69	60	74	80	56	NE. fr., clear.
May 10	13	.....	40	34	22	23	47	30	W. fr., clear.
May 13	14	.....	80	61	60	74	78	61	E. fr., clear.
May 14	31	.....	43	40	23	35	35	34	Do.
Sums	257	.....	427	372	297	354	416	365	
Means	26	.....	43	37	30	39	52	36	
May 15	28	.....	30	27	26	.....	.....	28	E. lt., fair.
May 17	55	.....	50	51	38	.....	.....	48	SE. fr., clear.
May 19	58	.....	71	38	30	.....	.....	49	NW. fr., clear.
May 20	150	.....	140	75	43	.....	.....	102	W. fr., clear.
May 21	135	.....	102	60	60	.....	.....	89	E. fr., clear.
May 22	151	.....	181	126	74	.....	.....	133	S. fr., clear.
May 23	70	.....	71	63	70	.....	.....	68	SW. br., fair.
June 7	131	.....	180	123	107	157	170	145	W. fr., fair.
June 10	58	.....	179	160	171	199	251	170	E. br., clear.
June 11	79	.....	143	106	343	520	30	202	SE. fr., clear.
Sums	915	.....	1,147	829	962	876	451	1,034	
Means	92	.....	115	83	96	292	150	103	
June 12	111	.....	143	131	131	170	231	153	Var. fr., clear.
June 13	27	.....	31	71	130	147	273	113	SE. fr., clear.
June 15	170	.....	199	180	146	171	149	169	E. br., clear.
June 26	63	.....	66	56	42	73	87	64	Var. fr., fair.
June 28	40	.....	67	23	26	29	47	39	S. fr., clear.
June 29	43	.....	47	23	19	31	72	39	W. fr , clear.
June 30	25	.....	31	19	16	34	48	29	Do.
July 2	35	78	81	51	51	58	108	66	Do.
July 3	22	51	47	27	19	27	52	35	E. fr., fair.
July 4	16	27	35	15	16	21	32	23	SW. br., fair.
Sums	552	156	747	596	596	761	1,099	730	
Means	55	52	75	60	60	76	110	73	

TABLE I.—*Potential on clear and fair days, Boston, Mass., July, 1886, to August, 1888*—Continued.

Date.	7 a. m.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	7 p. m.	11 p. m.	Means.	Remarks.
1887.									
July 8	41	125	86	75	75	74	88	81	E. fr., clear.
July 14	52	46	55	35	27	21	44	40	N. br., clear.
July 15	27	39	21	33	39	21	26	29	N. br., fair.
July 20	30	18	51	39	33	.....	.....	34	E. fr., clear.
July 26	12	18	59	59	63	.....	.....	43	S. fr., fair.
July 28	13	19	27	21	66	.....	.....	29	SW. fr., clear.
August 1	63	90	75	81	150	.....	.....	92	SE. fr., clear.
August 7	93	93	147	120	120	.....	.....	115	N. br., clear.
August 8	33	45	51	51	45	.....	.....	45	SE. fr., clear.
August 13	82	57	100	87	63	63	60	73	N. fr., clear.
Sums	446	550	672	601	681	179	218	581	
Means	45	55	67	60	68	45	54	58	
August 14	49	59	149	93	144	78	72	92	NW. fr., clear.
August 17	75	75	60	51	38	21	28	50	Do.
August 19	74	72	93	97	69	51	35	70	W. fr., clear.
August 21	81	180	135	120	153	79	53	114	SW. br., clear.
August 29	118	158	249	261	298	270	334	241	Var. fr., clear.
Sums	397	544	686	622	702	499	522	567	
Means	79	109	137	124	140	100	104	113	

SUMMARY.

Number of days.	7 a. m.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	7 p. m.	11 p. m.	Means.
(10)	257	.....	427	372	297	354	416	365
(10)	915	.....	1,147	829	962	876	451	1,034
(10)	552	156	747	596	596	761	1,099	730
(10)	446	550	672	601	681	179	218	581
(5)	397	544	686	622	702	499	522	567
Sums	2,567	1,250	3,679	3,020	3,238	2,669	2,706	3,277
Means	57	69	82	67	72	86	90	73

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1887.							
December 13	114	52	117	104	124	102	Clear.
December 14	240	182	109	252	299	216	Do.
1888.							
January 12	132	106	106	108	132	117	NW. fr., clear.
January 14	126	124	108	119	167	129	NW. lt., clear.
January 16	155	144	124	146	172	148	NW. fr., clear.
January 19	.....	151	110	106	185	138	Do.
January 20	172	133	133	133	236	161	NW. br., clear.
January 21	108	99	151	161	193	142	Do.
January 27	60	88	103	109	114	95	NW. high, clear.
January 28	118	127	147	143	191	145	NW. br., clear.
Sums	1,225	1,206	1,208	1,381	1,813	1,393	
Means	136	121	121	138	181	139	
February 1	398	392	254	208	257	303	N. fr., clear.
February 2	188	176	260	159	268	210	NW. br., clear.
February 6	172	233	250	210	205	214	Do.
February 9	170	128	122	112	142	135	W. br., clear.
February 13	743	405	338	692	957	627	SE. lt., clear.
February 15	86	108	108	119	108	106	NW. br., clear.
February 16	197	170	121	192	367	209	Do.
February 24	213	175	270	184	835	335	N. lt., clear.
March 15	83	135	189	148	154	142	W. br., clear.
March 17	102	107	108	118	115	110	Do.
Sums	2,352	2,029	2,020	2,142	3,408	2,391	
Means	235	203	202	214	341	239	

TABLE I.—*Potential on clear and fair days, Boston, Mass., July, 1886, to August, 1888*—Continued.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.	Remarks.
1888.							
April 13	44	20	23	23	65	35	NW. br., clear.
April 27	307	179	167	494	709	371	E. fr., clear.
April 28	122	156	379	433	204	259	SE. lt., fair.
May 21	46	47	34	41	69	47	NW. fr., clear.
May 22	298	325	127	468	746	393	E. fr., fair.
June 4	219	96	535	284	129	253	Var. fr., fair.
June 6	43	73	37	58	82	59	SW. br., clear.
June 8	148	138	267	162	419	227	E. br., clear.
June 12	88	48	106	163	64	94	SE., fr., clear.
June 23	39	80	115	57	62	71	W. fr., clear.
Sums	1,354	1,162	1,790	2,183	2,549	1,809	
Means	135	116	179	218	255	181	
July 2	1,400	1,160	1,000	1,110	400	1,014	NE. fr., clear.
July 3	2,100	2,360	1,970	850	1,370	1,730	E. fr., clear.
July 4	352	317	493	563	528	451	SW. br., clear.
July 6	81	60	165	406	432	229	NW. br., clear.
July 11	261	106	35	0	18	84	SW. br., clear.
July 14	665	211	400	880	1,160	663	NW. fr., fair.
July 16	1,440	1,300	1,410	1,230	1,317	1,339	E. fr., clear.
July 17	1,140	510	615	490	985	748	SE. fr., clear.
July 24	208	425	348	475	685	428	W. fr., fair.
July 25	895	745	650	630	970	778	Var. fr., clear.
Sums	8,542	7,194	7,086	6,634	7,865	7,464	
Means	854	719	709	663	786	746	
July 30	.....	495	520	420	440	469	NW. fr., clear.
August 10	920	800	605	510	515	670	W. fr., clear.
August 14	250	265	258	420	955	430	NW. br., fair.
August 23	680	575	550	445	600	570	NW. fr., clear.
August 24	700	752	585	725	640.	680	W. br., clear.
August 25	655	530	370	435	270	452	W. fr., clear.
August 30	860	790	650	660	725	737	W. br., clear.
Sums	4,065	4,207	3,538	3,615	4,145	4,008	
Means	678	601	505	516	592	573	

SUMMARY.

No. of days.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	5 p. m.	Means.
(10)	1,225	1,206	1,208	1,381	1,813	1,393
(10)	2,352	2,029	2,020	2,142	3,408	2,391
(10)	1,354	1,162	1,790	2,183	2,549	1,809
(10)	8,542	7,194	7,086	6,634	7,865	7,464
(7)	4,065	4,207	3,538	3,615	4,145	4,008
Sums	17,538	15,798	15,642	15,955	19,780	17,065
Means	390	336	333	340	421	364

TABLE J.—*Potential on clear and fair days, St. Louis, Mo.*, 1861.

[A. Wislizenus, M. D., observer.]

Date.	6 a. m.	9 a. m.	12 m.	3 p. m.	6 p. m.	9 p. m.	Means.	Remarks.
1861.								
January 1	38	57	76	31	24	40	44	SE. lt., clear.
January 12	52	67	57	42	55	42	52	SE. fr., fair.
January 18	24	38	34	24	29	17	28	SW. br., clear.
January 24	31	40	24	38	52	42	38	Do.
January 25	116	76	57	38	42	34	60	SE. fr., fair.
January 27	15	31	42	36	57	45	38	W. fr., clear.
February 4	45	45	64	34	45	36	45	NW. lt., fair.
February 5	55	47	45	42	52	50	48	W. fr., clear.
February 6	31	45	24	29	17	15	27	SW. fr., clear.
February 8	4	17	15	34	29	11	18	SE. fr., clear.
Sums	411	463	438	348	402	332	398	
Means	41	46	44	35	40	33	40	
February 20	47	40	45	11	38	38	36	NW. br., fair.
February 26	17	29	45	17	22	13	24	SE. lt., clear.
March 5	45	34	15	17	24	24	26	W. fr., fair.
March 10	15	34	38	34	42	27	32	Do.
March 11	19	27	11	13	15	4	15	SE. fr., fair.
March 18	15	17	15	8	34	29	20	Do.
March 21	57	72	29	27	27	29	40	SE. lt., fair.
April 16	45	27	27	29	29	34	32	N. br., fair.
April 19	24	36	13	13	19	22	21	NW. fr., clear.
April 24	15	6	4	15	24	90	26	W. lt., clear.
Sums	299	322	242	184	274	310	272	
Means	30	32	24	18	27	31	27	
April 28	22	45	40	38	22	24	32	S. lt., clear.
April 30	17	19	17	13	11	15	15	SW. lt., clear.
May 1	40	29	34	22	29	24	30	NE. fr., clear.
May 2	22	34	24	17	15	17	22	SE. fr., fair.
May 8	31	17	15	4	4	13	14	W. lt., fair.
May 14	36	40	29	22	24	38	32	SW. lt., clear.
May 15	52	45	27	17	22	24	31	W. br., fair.
May 16	57	52	31	27	15	31	36	N. lt., clear.
May 17	34	47	42	31	27	15	33	E. lt., fair.
May 18	8	38	45	22	19	13	24	SE. lt., fair.
Sums	319	366	304	213	188	214	269	
Means	32	37	30	21	19	21	27	
May 22	27	29	34	19	15	11	22	SE. lt., clear.
May 25	15	4	4	11	17	4	9	SW. fr., fair.
May 27	15	8	8	6	8	13	10	W. br , fair.
June 5	31	29	34	17	19	13	24	SE. fr., fair.
June 9	2	4	8	13	11	2	7	E. fr., fair.
June 10	4	13	8	19	15	17	13	SE. fr., clear.
June 12	27	22	13	11	19	17	18	NW. fr., clear.
June 13	13	15	17	15	15	13	15	SE. lt., fair.
June 14	11	13	8	6	4	2	7	S. lt., clear.
June 16	11	2	2	4	6	8	6	N. br., fair.
Sums	156	139	136	121	129	100	129	
Means	16	14	14	12	13	10	13	
June 20	19	4	2	2	4	2	6	SW. br., fair.
June 21	4	2	4	4	6	2	4	SW. fr., clear.
July 1	2	8	4	15	13	13	9	N. br., fair.
July 2	13	22	13	11	27	24	18	NE. fr., clear.
July 3	31	13	15	11	8	8	14	SE. lt. clear.
July 4	17	11	11	11	13	4	11	Do.
July 6	2	2	2	2	8	4	3	S. lt., fair.
July 10	17	15	15	22	24	19	19	NW. br., fair.
July 11	11	15	17	13	22	13	15	W. fr., fair.
July 13	15	11	11	11	11	13	12	SE. lt., fair.
Sums	131	103	94	102	136	102	111	
Means	13	10	9	10	14	10	11	

TABLE J.—*Potential on clear and fair days, St. Louis, Mo.*, 1861—Continued.

Date.	6 a. m.	9 a. m.	12 m.	3 p. m.	6 p. m.	9 p. m.	Means.	Remarks.
1861.								
July 16	4	6	8	8	11	13	8	NW. fr., fair.
July 17	24	6	8	11	6	4	10	SE. lt., fair.
July 23	22	2	8	4	6	11	9	N. fr., clear.
July 24	8	6	4	4	8	4	6	SE. lt., clear.
July 25	2	2	13	4	8	8	6	S. lt., fair.
July 29	2	2	6	2	2	2	3	SW. fr., fair.
July 30	6	2	8	2	2	4	4	S. lt., clear.
July 31	4	6	4	4	2	2	4	SW. lt., clear.
August 1	4	2	13	13	17	2	8	NE. lt., fair.
August 2	2	8	11	19	19	13	12	N. fr., clear.
Sums	78	42	83	71	81	63	70	
Means	8	4	8	7	8	6	7	
August 3	2	11	13	11	13	15	11	NE. lt., fair.
August 7	4	4	2	4	11	4	5	SE. lt., clear.
August 14	4	11	19	13	17	4	11	NE. lt., fair.
August 15	27	34	17	11	17	11	20	Do.
August 16	2	13	19	24	22	13	16	NE. lt., clear.
August 17	13	17	11	15	19	4	13	NE. fr., clear.
August 23	6	8	15	22	17	15	14	Do.
August 27	6	6	8	15	11	2	8	SE. lt., fair.
August 29	4	6	11	8	8	6	7	NW. fr., clear.
August 30	6	4	11	15	8	8	9	NE. lt., clear.
Sums	74	114	126	138	143	82	114	
Means	7	11	13	14	14	8	11	
August 31	2	4	17	19	8	2	9	SE. lt., clear.
September 1	2	2	2	6	4	2	3	SE. fr., clear.
September 5	4	13	2	2	6	2	5	S. lt., fair.
September 6	8	4	15	8	17	6	10	NW. fr., fair.
September 7	4	13	8	8	17	6	9	N. fr., fair.
September 8	6	6	11	4	2	2	5	N. fr., clear.
September 9	4	6	11	4	2	4	5	E. fr., clear.
September 18	2	2	2	4	11	4	4	SE. fr., fair.
September 19	2	2	2	6	4	2	3	S. fr., clear.
September 22	2	4	11	8	11	2	6	SW. lt., clear.
Sums	36	56	81	69	82	32	59	
Means	4	6	8	7	8	3	6	
September 23	11	13	15	27	40	11	20	NE. lt., clear.
September 28	22	34	15	15	31	11	21	W. fr , fair.
October 6	2	15	24	13	19	8	14	NW. fr., fair.
October 7	13	11	11	22	34	15	18	S. fr., fair.
October 8	27	27	17	15	11	8	18	SE. fr., clear.
October 11	15	34	22	27	29	6	22	SW. fr., clear.
October 12	13	90	17	8	38	15	30	W. fr., clear.
October 13	22	36	15	13	15	2	17	S. lt., clear.
October 14	31	31	13	19	22	11	21	SW. lt., fair.
October 20	17	27	17	6	27	22	19	NE. fr., clear.
Sums	173	318	166	165	266	109	200	
Means	17	32	17	16	27	11	20	
October 21	24	29	34	15	36	13	25	E. lt., clear.
October 23	11	31	45	15	13	27	24	W. fr., clear.
October 27	22	52	42	50	15	13	32	E. lt., clear.
October 28	31	34	29	27	22	24	28	SE. fr., clear.
November 15	50	55	27	19	34	22	34	NW. fr., clear.
November 20	8	17	15	13	36	31	20	SW. fr., clear.
November 27	31	34	34	35	100	38	45	W. fr., fair.
December 4	38	116	50	38	47	19	51	SE. fr., clear.
December 8	2	4	2	2	2	2	2	S. fr., fair.
December 9	2	2	2	2	8	2	3	Do.
Sums	219	374	280	216	313	191	264	
Means	22	37	28	22	31	19	26	

TABLE J.—*Potential on clear and fair days, St. Louis, Mo.*, 1861—Continued.

Date.	6 a. m.	9 a. m.	12 m.	3 p. m.	6 p. m.	9 p. m.	Means.	Remarks.
1861.								
December 11	76	34	40	31	76	90	58	N. fr., clear.
December 12	17	64	50	47	45	45	45	SE. lt., clear.
December 13	50	85	76	116	40	34	67	SE. lt., fair.
December 18	34	42	34	29	29	27	32	SW. lt., clear.
December 19	22	36	22	29	34	17	27	SW. fr., fair.
December 24	15	55	45	17	34	15	30	SE. fr., clear.
December 27	19	76	47	57	85	22	51	E. lt., clear.
December 28	42	50	55	42	52	31	45	SE. fr., fair.
December 29	19	57	64	42	55	34	45	NW. lt., clear.
December 31	45	64	52	27	22	24	39	S. fr., fair.
Sums	339	563	485	437	472	339	439	
Means	34	56	48	44	47	34	44	

MEANS.

	6 a. m.	9 a. m.	12 m.	3 p. m.	6 p. m.	9 p. m.	Means.
Sums for 10 days ..	411	463	438	348	402	332	398
Do	299	322	242	184	274	310	272
Do	319	366	304	213	188	214	269
Do	156	139	136	121	129	100	129
Do	131	103	94	102	136	102	111
Do	78	42	83	71	81	63	70
Do	74	114	126	138	143	82	114
Do	36	56	81	69	82	32	59
Do	173	318	166	165	266	109	200
Do	219	374	280	216	313	191	264
Do	339	563	485	437	472	339	439
Total sums	2,235	2,860	2,435	2,064	2,486	1,874	2,325
Mean for 1 day.	20	26	22	19	23	17	21

TABLE K.—*Potential on clear and fair days, New Haven, Conn., August* 1, 1886, *to July* 31, 1887.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.	Remarks.
1886.						
August 9	11.5	19.6	20.9	54.3	26.6	SW. lt., $\frac{2}{10}$ clouds in p. m.
October 4	41.8	20.0	38.5	29.2	32.4	SW. lt., clear.
October 5	33.7	10.4	10.6	7.0	15.4	NE. lt., clear.
October 8	16.2	17.4	12.5	.....	15.4	Var. lt., clear.
October 9	31.8	9.6	9.9	9.7	15.2	S. lt., clear.
October 11	18.6	10.4	22.4	11.8	15.8	S. lt.
October 12	10.8	24.7	33.9	15.7	21.3	W. lt.
October 22	16.4	14.2	17.5	15.4	15.9	W.
October 23	38.6	17.8	14.0	.....	23.5	N. lt.
November 9	13.4	14.6	17.0	17.2	15.6	SW. lt.
Sums	232.8	158.7	197.2	160.3	197.1	
Means	23.3	15.9	19.7	20.0	19.7	
November 22	19.2	18.7	19.3	15.4	18.2	NW. lt.
November 27	65.9	57.9	18.4	11.8	38.5	SW. lt.
December 8	38.1	33.0	44.8	58.0	43.5	NW. lt.
December 9	56.0	46.0	28.3	38.2	42.1	Do.
December 10	67.0	52.5	65.4	53.4	59.6	W. lt.
December 11	37.5	.....	40.6	40.4	39.5	Do.
December 17	61.0	102.0	34.0	50.6	61.9	SW. lt.
December 21	30.9	59.4	49.8	47.5	46.9	W. fresh.
December 25	11.0	14.7	11.8	13.1	12.6	NW. br.
1887.						
January 3	36.0	32.6	31.5	34.4	33.6	NW.
Sums	422.6	416.8	343.9	362.8	396.4	
Means	42.3	46.3	34.4	36.3	39.6	
January 4	55.7	76.9	59.7	40.6	58.2	NE.
January 11	28.0	32.2	28.5	10.2	24.8	W.
January 27	26.2	28.5	26.9	28.1	27.4	NW.
February 9	16.9	16.8	14.2	17.0	16.2	NW., $\frac{2}{10}$ clouds.
February 14	22.5	28.5	24.5	18.6	23.5	S., $\frac{3}{10}$ clouds in p. m.
February 19	10.7	13.0	20.9	15.2	15.0	W. clear.
February 25	12.1	16.6	12.7	16.6	14.5	NW. clear, $\frac{1}{10}$ at 3 p. m.
March 8	22.3	16.0	12.3	11.9	15.6	NW. clear.
March 26	19.1	26.0	26.6	28.3	25.0	W. clear.
April 6	10.4	1.4	6.1	7.8	6.4	NW. clear.
Sums	223.9	255.9	232.4	194.3	226.6	
Means	22.4	25.6	23.2	19.4	22.7	
April 8	28.1	21.8	19.5	21.0	22.6	S. clear.
May 13	7.1	13.7	5.9	16.4	10.8	N. clear.
May 19	18.4	1.6	—12.8	2.7	2.5	Do.
June 11	16.0	15.4	11.5	41.5	21.1	NE. clear, $\frac{1}{10}$ at 11 a.m.
June 15	25.0	20.1	36.5	18.5	25.0	S. clear.
June 29	24.6	55.5	10.5	24.0	28.6	Do.
June 30	27.0	26.8	6.5	9.1	17.4	W. clear.
July 2	27.5	32.0	39.5	14.0	28.2	SW. clear.
Sums	173.7	186.9	117.1	147.2	156.2	
Means	21.7	23.4	14.6	18.4	19.5	

SUMMARY.

[Actual readings.]

Number of days.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.
(10)	232.8	158.7	197.2	160.3	197.1
(10)	422.6	416.8	343.9	362.8	396.4
(10)	223.9	255.9	232.4	194.3	226.6
(8)	173.7	186.9	117.1	147.2	156.2
Sums (38)	1,053.0	1,018.3	890.6	864.6	976.3
Means	27.7	27.5	23.4	24.0	25.7

TABLE K.—*Potential on clear and fair days, New Haven, Conn., August* 1, 1886, *to July* 31, 1887—Continued.

Date.	9 a. m.	11 a. m.	1 p. m.	3 p. m.	Means.
1886.					
August 9	.43	.74	.79	2.04	1.00
October 4	1.26	.62	1.18	.91	1.00
October 5	2.19	.68	.68	.45	1.00
October 8	1.05	1.13	.81	.....	1.00
October 9	2.09	.63	.65	.64	1.00
October 11	1.18	.66	1.42	.75	1.00
October 12	.51	1.16	1.59	.74	1.00
October 22	1.03	.89	1.10	.97	1.00
October 23	1.64	.76	.60	.....	1.00
November 9	.96	.94	1.09	1.10	1.00
Sums	12.24	8.21	9.91	7.60	10.00
Means	1.22	.82	.99	.95	1.00
November 22	1.05	1.02	1.06	.85	1.00
November 27	1.71	1.50	.48	.31	1.00
December 8	.88	.76	1.03	1.33	1.00
December 9	1.33	1.09	.67	.91	1.00
December 10	1.14	.88	1.09	.90	1.00
December 11	.95	.....	1.03	1.02	1.00
December 17	.98	1.64	.55	.82	1.00
December 21	.66	1.26	1.06	1.00	1.00
December 25	.87	1.16	.94	1.04	1.00
1887.					
January 3	1.08	.97	.94	1.03	1.00
Sums	10.65	10.28	8.85	9.21	10.00
Means	1.06	1.14	.88	.92	1.00
January 4	.96	1.32	1.03	.70	1.00
January 11	1.12	1.26	1.15	.41	1.00
January 27	.96	1.04	.98	1.02	1.00
February 9	1.04	1.04	.88	1.05	1.00
February 14	.96	1.21	1.04	.79	1.00
February 19	.71	.87	1.39	1.01	1.00
February 25	.83	1.14	.88	1.14	1.00
March 8	1.43	1.03	.79	.76	1.00
March 26	.76	1.04	1.06	1.13	1.00
April 6	1.62	.22	.95	1.22	1.00
Sums	10.39	10.17	10.15	9.23	10.00
Means	1.04	1.02	1.02	.92	1.00
April 8	1.24	.96	.86	.93	1.00
May 13	.66	1.26	.55	1.52	1.00
May 19	7.40	.64	—5.10	1.08	1.00
June 11	.76	.73	.54	1.96	1.00
June 15	1.00	.80	1.46	.74	1.00
June 29	.86	1.94	.37	.84	1.00
June 30	1.55	1.54	.37	.52	1.00
July 2	.98	1.13	1.40	.50	1.00
Sums	14.45	9.00	.45	8.09	8.00
Means	1.81	1.12	.06	1.01	1.00

SUMMARY.

[Relative potential.]

No. of days.	9 a. m	11 a m.	1 p. m.	3 p. m.	Means.
(10)	12.24	8.21	9.91	7.60	10.00
(10)	10.65	10.28	8.85	9.21	10.00
(10)	10.39	10.17	10.15	9.23	10.00
(8)	14.45	9.00	.45	8.09	8.00
Sums (38)	47.73	37.66	29.36	34.13	38.00
Means	1.26	1.02	.77	.95	1.00

TABLE L.—*Potential on days on which precipitation occurred at the place of observation, Terre Haute, Ind., March 30, 1887, to August 25, 1888.*

[Extract from daily journal.]

Date.	Remarks.
1887.	
Apr. 1	Lt. rain and sleet *b. 6 a. m.; first observation at 8:50 a. m.; negative potential, 8:50 to 9:15 a. m.; rain †e. 9:30 a. m. Threatening weather with negative again at 11:55 a. m.; lt. rain 11:56 a. m. to 12 m.; negative during rain; variable positive and negative from 12 m. to 2:30 p. m., with weather clearing and threatening by turns
Apr. 6	Threatening, with variable positive and negative, from 1 to 5 p. m.; rained during the night.
Apr. 16	Threatening weather, with a few flakes of dry snow, 11 to 11:02 a. m.; positive all day.
Apr. 18	Lt. rain and sleet ‡b. d. n., changed to snow 9:55 a. m.; hy. snow until 1 p. m.; lt. snow e. 4 p. m. First observation 9 a. m.; negative until 11:30 a. m.; variable ± until 1 p. m.; positive rest of the day.
Apr. 20	Lt. rain b. 7 a. m., e. 10:44 a. m., 0.03 inch; variable positive and negative from 9 to 10:15 a. m. Trace of rain from 7 to 7:15 p. m.; negative at 7:10 p. m.; no other observations after 5:45 p. m.
Apr. 21	Threatening at 4 p. m.; negative from 4:30 to 4:50 p. m.; lt. rain b. 5:15 p. m.; lt. and hy. rains all evening; variable positive and negative from 5:20 to 6:20 p. m. No observations after 6:20 p. m. The potential was very high during the rain, and sparks frequently passed from the needle to the quadrants.
Apr. 22	Rain b. d. n.; thunderstorm and lightning b. 9:36 a. m.; e. 11 a. m. Fresh SE. winds before the storm changed to W. and NW. gale during, and then to light variable. After the storm the wind was fresh easterly. Rain e. 11:34 a. m. High variable positive and negative from 9 a. m. to 12 m. At times during the storm the sky was so dark and threatening that lights had to be used to read the scale, and almost continuous sparks passed between the needle and quadrants. Cloudy from 12 m. to 5:30 p. m.; then began to threaten; variable positive and negative from 5:40 to 6:25 p. m.; a few drops of rain at 6:37 p. m.; high positive until 7:05 p. m.; positive and negative 7:05 to 7:09p. m. No observations after 7:15 p. m. Thunderstorm south of the station at 7:06 p. m. with hy. rain; lt. rain began at the station 7:20, e. 8 p. m., 0.01 inch.
Apr. 28	A few drops of rain at 2:55 p. m.; no observations between 1 and 3 p. m.; positive at all observations; lower at 3 p. m. than at any other time observed.
May 1	Thunderstorm and lightning b. 10:40, e. 11:05 a. m.; rain and hail b. 11, e. 11:08 a. m., 0.02 inch. No observations until 11:10 a. m.; variable positive and negative 11:10 to 11:20 a. m., when it became steady positive.
May 2	Threatening at 9:30 a. m. to 12 m.; negative from 12 m. to 12:23 p. m.; then variable positive and negative until 1:10 p. m. Thunder and lightning from 12:10 to 12:55 p. m.; lt. rain from 12:53 to 1 p. m.
May 5	Lt. rain §b. d. n., e. 10:50 a. m.; variable positive and negative from 9 to 11 a. m.; negative from 11 a. m. to 12:15 p. m.; hy. rain from 2 to 2:10 p. m. No observations between 1 and 3 p. m. Fair from 3 to 5 p. m.; threatening at 5:05 p. m.; negative from 5:11 to 5:50 p. m.; then variable ± until 6:40 p. m., when it became steady positive; lt. rain 5:20 to 6:30 p. m.; distant thunder at 6 p. m.; almost continuous sparks from 5:55 to 6:10 p. m.
May 6	Threatening at 1 p. m.; variable positive and negative from 3 to 5 p. m.; no observations after 6:30 p. m.; rain began at 8 p. m.
May 11	Variable positive and negative from 3 to 6 p. m., generally neegative; thunder and lightning almost continuous from 3:42 to 4:45 p. m.; lt. rain b. 3:45, e. 4:30 p. m.; heaviest part of the storm south of the city; positive from 6 to 7 p. m.; sparks between the needle and quadrants during the thunder.
May 17	Lt. rain mist 11:31 to 11:33 a. m. and from 12:55 to 1:05 p. m., amount, trace; positive at all observations and during both rains.
May 21	Variable positive and negative from 10 a. m. to 2:20 p. m.; negative from 2:20 to 3:10 p. m.; positive rest of the day; thunder and lightning from 1:20 to 3 p. m.; hy. rain from 1:30 to 2:40 p. m.; sparked from 2:20 to 2:25 p. m. and at 2:55 p. m.
May 24	Threatening at 3:20 p. m.; variable positive and negative from 3:30 to 4:15 p. m.; negative from 4:15 to 5:05 p. m.; variable positive and negative 5:05 to 5:30 p. m.; thunder from 4:36 to 5:15 p. m.; electricity sparked during the thunder; lt. rain from 5 to 5:05 p. m., trace.
May 30	Rain b. d. n., e. 9:30 a. m.; first observation at 9 a. m.; variable positive and negative from 9 to 10:32 a. m.; low positive in afternoon; no observations after 6 p. m.; thunderstorm from 7:30 to 8:30 p. m.
May 31	Thunder and lightning from 1:05 to 2:40 p. m.; variable positive and negative from 1 to 3:45 p. m., with frequent sparks; hy. rain b. 1:41 p. m., changed to lt. rain 2 p. m., e. 3:06 p. m.
June 5	Threatening at 1:30 p. m.; negative from 3 to 3:45 p. m.; hy. rain from 3:30 to 3:46 p. m., 0.04 inch; lt. rain from 4:56 to 4:59 p. m.; negative from 4:57 to 5 p. m.
June 9	A trace of rain at 2 p. m.; no observations between 1 and 3 p. m.; positive at all observations.
June 20	Threatening and negative from 12 m. to 12:30 p. m.; no observations from 12:30 to 2:50 p. m.; thunderstorm from 1:20 to 2 p. m.; trace of rain from 1:30 to 1:40 p. m.
June 22	Variable positive and negative from 11:05 a. m. to 5 p. m.; trace of rain from 1 to 1:02 p. m.; negative during the rain.

* Began.
† Ended.
‡ Began during night, from about 11 p. m. to daylight.
§ Began during night, ended ***.

TABLE L.—*Potential on days on which precipitation occurred at the place of observation, Terre Haute, Ind., March* 30, 1887, *to August* 25, 1888—Continued.

Date.	Remarks.
1887.	
June 30	Negative from 12 m. to 12:30 p. m.; lt. rain from 1:25 to 2 p. m.; no observations during the rain. Threatening and negative from 4:10 to 4:30 p. m.; variable positive and negative until 4:48 p. m.; lt. rain b. 4:26, e. 4:42 p. m.
July 2	Threatening at 3 p. m.; variable positive and negative from 3:45 to 7:10 p. m.; distant thunder at 4:15 p. m.; trace of rain from 7:06 to 7:07 p. m.; negative during rain; no observations after 7:10 p. m.
July 3	Trace of rain from 10:45 to 10:46 a. m.; no observations until 11 a. m., after which it was positive.
July 4	Variable positive and negative from 3 to 4:30 p. m.; distant thunder from 3:30 to 3:35 p. m.; lt. rain b. 3:48, e. 4:20 p. m.
July 6	Variable positive and negative from 10 a. m. to 6 p. m. (R. R. trains seemed to influence the potential); lt. rain from 5:19 to 5:55 p. m.; thunderstorm from 5:32 to 5:58 p. m.; frequently sparked during the rain. From 6 to 6:30 p. m. the potential was high positive and sparked so much that readings could not be taken; distant thunder until 8:30 p. m.; no observations after 6:30 p. m.
July 8	Threatening at 3 p. m.; thunderstorm and lightning from 3:30 to 6 p. m.; variable positive and negative from 3:30 to 6:15 p. m.; lt. rain from 4:46 to 5:45 p. m.
July 18	Positive up to 1 p. m.; no observations from 1 to 2:30 p. m.; trace of rain from 1:50 to 2 p. m. Negative from 2:30 to 6:45 p. m.; no observations after 6:45 p. m. Thunderstorm b. 2:05 p. m., continued all the afternoon until 8 p. m.; lightning continued until 9 p. m.; a trace of rain from 5:15 to 5:16 p. m.
July 21	Threatening at 1 p. m.; negative from 3:15 to 5:30 p. m.; thunderstorm and lightning from 3:30 to 7 p. m.; lt. rain from 3:31 to 3:35 p. m.; hy. rain from 5:50 to 7:05 p. m.; the potential was not over 1,500 volts; no observations after 6 p. m.
July 22	Variable positive and negative from 1 to 7 p. m.; very high potential; sparked (R. R. trains seemed to have an influence); lt. rain b. 5:15, e. 5:50 p. m.; high positive during the rain; negative just before and just after it.
Aug. 4	Positive until 12 m.; no observations from 12 m. to 2:30 p. m.; thunder and lightning from 2:20 to 6 p. m.; a trace of rain from 2:20 to 2:25 p. m.; hy. rain from 4:14 to 5:35 p. m.; negative from 2:30 to 3:15 p. m.; variable positive and negative from 4:08 to 4:35 p. m.; negative from 4:47 to 6 p. m.; then positive to 7 p. m.
Aug. 5	Thunder and lightning from 12:50 to 3:30 p. m.; hy. rain from 2:15 to 3:40 p. m.; high positive from 12:45 to 1:20 p. m.; variable positive and negative from 1:25 to 4:30 p. m.
Aug. 11	Thunder and lightning from 8 to 10:47 a. m.; lt. rain b. 8:25, e. 9:29 a. m. Observations began at 9 a. m. Variable positive and negative from 9 to 10:45 a. m.; positive rest of the day; hy. thunderstorm and rain from 9 p. m. to 1 a. m. of 12th.
Aug. 17	Lt. rain at intervals from 8:40 a. m. to 12:35 p. m. Observations taken every half hour from 9 a. m.; the potential was low positive all the time.
Aug. 21	Trace of rain from 3:45 to 3:49 p. m. No observations between 1 and 4 p. m.; positive at all observed times.
Aug. 22	Lt. rain b. d. n., e. 9:45 a. m.; positive at 9 a. m., the only observation during the rain.
Sept. 22	Trace of rain from 1 to 2:45 p. m. No observations between 12:45 to 3 p. m.; low positive all day; insulation poor.
Sept. 26	A high positive potential at 12 m.; lt. drizzling rain b. 12:10 p. m. and continued all day; negative from 3:45 to the last observation at 6:30 p. m.
Sept. 27	Lt. rain mist all night and all day; negative at 11 a. m. and 1 p. m.; positive at the other observations; low potential; insulation very poor.
Sept. 29	Lt. rain mist b. 4:04 p. m., changed to hy. rain at 4:30, e. 5:48 p. m.; thunder and lightning from 4:30 to 5:10 p. m.; negative from 4:15 to 4:35 p. m.; then variable positive and negative until 5:50 p. m.
Sept. 30	A trace of rain from 9:37 to 9:38 a. m.; positive all the time except for a few minutes at 10:15 a. m., when it was negative.
Oct. 10	Lt. rain b. d. n., e. 11:50 a. m.; b. 1., e. 1:50 p. m.; b. 4:02, e. 4:10 p. m.; negative from 9 to 11 a. m.; variable positive and negative from 11 a. m. to 4:10 p. m.
Oct. 11	Hy. rain b. 4:08 p. m., e. 5:48 p. m.; positive all day from 9 a. m. to 3 p. m. No observations between 3 and 5 p. m.; variable positive and negative from 5 to 5:50 p. m.; then positive until 7 p. m.; negative and sparks during the rain, which was large drops.
Oct. 20	Threatening at 9 a. m.; trace of rain from 10:50 to 10:55 a. m.; positive between 9 and 11 a. m.; variable positive and negative from 11:10 a. m. to 5:30 p. m., with west to northwest gale.
Oct. 23	Threatening, with south gale, at 10:30 a. m.; lt. rain b. 1:10, e. 2:15 p. m., 0.02 inch; positive from 10:30 to 11:30 a. m.; negative from 12 m. to 1 p. m.; no observations after 1 p. m.
Nov. 9	A trace of rain from 8:20 to 8:50 a. m.; first observation at 9 a. m.; variable positive and negative until 11 a. m.; rained in the afternoon and evening; no observations after 1 p. m.
Nov. 19	A trace of snow from 8:30 to 9:25 a. m.; threatening weather the remainder of the day. A cold wave coming; temperature fell from 37° at 8 a. m. to 30° at 12 m., and to 12° during the night; west gale winds. Variable positive and negative from 9 to 10 a. m.; negative 500 to 1,000 volts from 10 a. m. all day.
Nov. 23	Rain b. 7:50 a. m., e. during night of 24th; amount, 1.08 inches; variable positive and negative all day from 9 a. m. to 5 p. m.
Nov. 25	Lt. rain b. d. n., e. 2:50 p. m.; steady negative from 9 a. m. to 1 p. m.; positive from 3 to 5 and variable positive and negative from 7 to 8 p. m., followed by rain during the night.

TABLE L.—*Potential on days on which precipitation occurred at the place of observation, Terre Haute, Ind., March* 30, 1887, *to August* 25, 1888—Continued.

Date.	Remarks.
1887.	
Nov. 26	Lt. rain b. d. n. and continued at intervals all day; variable positive and negative all day from 9 a. m. to 5 p. m.; low potential.
Dec. 2	Lt. rain b. d. n. continued all day, 0.61 inch; negative from 9 a. m. to 1 p. m. and positive from 3 to 5 p. m.; low steady potential; no special observations.
Dec. 3	Lt. rain continued all night and e. 1:05 p. m.; amount, 0.55 inch; variable positive and negative from 9 a. m. to 12 m.; positive from 1 to 5 p. m.
Dec. 7	Lt. rain mist b. 7 a. m., e. 1:30 p. m., 0.07 inch; variable positive and negative from 9 to 11:30 a. m.
Dec. 9	Lt. rain mist from 9:10 a. m. to 4:50 p. m., 0.03 inch; low positive potential at all regular observations; no negative observed.
Dec. 10	Lt. rain b. 10 p. m. of 9th and continued as a mist all day; amount, 0.72 inch; no negative observed; low positive at all the regular observations; insulation on the 9th and 10th was poor.
Dec. 15	A trace of lt. dry snow mist from 6 a. m. to 4:15 p. m.; variable positive and negative from 9:30 to 9:50 a. m. and from 2:50 to 3:10 p. m.; positive the rest of the time; low potential.
Dec. 20	Lt. rain b. 6 a. m., changed to snow 5:50 p. m., e. 9:15 p. m.; negative all day from 9 a. m. to 5:10 p. m.; then variable positive and negative until 5:35 p. m.; then high positive during the snow up to the last observation at 6:40 p. m. The wind was light easterly all day until 5 p. m., when it suddenly changed to SW. fresh; then at 5:10 p. m. to W. gale. The temperature was 43° at 5, 35° at 5:10, 32° at 5:30, 28° at 5:50, and 26° at 6:15 p. m. Amount of rain and snow, 0.61 inch. Sparks between the needle and quadrants during the snow.
Dec. 23	A trace of snow from 11:30 to 11:45 a. m.; no observations during the snow; positive at 11 a. m. and 1 p. m.
Dec. 26	A trace of snow from 8:50 to 9:30 a. m.; first observation at 9 a. m.; no negative observed.
Dec. 30	Lt. snow b. 1:10 p. m. and continued during the night; low positive all morning; high positive all afternoon during the snow. Sparks frequently passed between the needle and quadrants.
Dec. 31	The snow changed to rain during the night; lt. rain all day. Variable positive and negative all day from 9 a. m. to 5 p. m.
1888.	
Jan. 5	Dense fog at 9 a. m.; lt. fog all day; lt. rain mist b. 10:15 a. m., e. 6:15 p. m., 0.02 inch. Variable positive and negative from 9 to 10 a. m. and from 3 to 5 p. m.
Jan. 6	Lt. rain b. 10 p. m. of the 5th, rained hard during the night; lt. rain all day, 1.16 inches. Variable positive and negative all day from 9 a. m to 5 p. m.
Jan. 7	Rained all night, e. 9:45 a. m.; b. 10:30 a. m., and continued as a light rain until during the night. Variable positive and negative all day from 9 a. m. to 5 p. m.
Jan. 9	A trace of snow from d. n. to 10 a. m.; just an occasional flake. First observation at 9 a. m. No negative observed during the snow. Low positive at 1 and 3 p. m. No observations between 3 and 4 p. m.; lt. snow b. 4 p. m., e. d. n., 0.02 inch. The dry snowflakes looked like pieces of broken needles $\frac{1}{8}$ to $\frac{1}{4}$ of an inch long and very narrow. From 4 to 6 p. m. the potential was variable positive, with an occasional negative.
Jan. 12	Lt. snow b. 12:05 p. m.; changed to sleet at 2 p. m.; changed to moist snow at 3:30 p. m.; changed to rain at 5:30 p. m.; rain e. d. n.; amount of melted sleet and snow, 0.21 inch; amount of rain, 0.30 inch. Positive in the morning. No observations from 11 a. m. to 12 m.; variable positive from 12 m. to 1 p. m. during the snow. No observations from 1 to 2:30 p. m.; negative all afternoon from 2:30 to 6 p. m., during sleet and rain.
Jan. 17	A trace of snow (occasional flakes) from 11:05 a. m. to 5:30 p. m. High variable positive, with sparks, from 10 to 11 a. m.; low positive the rest of the time observed.
Jan. 25	A trace of snow from d. n. to 10:05 a. m. No observations before 9 a. m.; positive after that hour; varied from 50 to 1,000 volts.
Jan. 30	Lt. rain mist from 3:30 to 7 p. m., 0.01 inch. Potential positive 800 volts at 1 p. m., 200 at 3 p. m., and 600 at 5 p. m.; no special observations.
Feb. 4	Lt. rain during the night and rain mist all day, changed to snow at 6, e. 8:50 p. m., 0.15 inch. Positive from 9 to 11:30 a. m.; then variable positive and negative until 1 p. m.; positive from 3 to 5 p. m.
Feb. 7	Lt. rain mist from 3:05 to 6:50 p. m., 0.01 inch. Falling positive all morning; no observations from 1 to 3 p. m.; no negative observed in the afternoon.
Feb. 8	Lt. snow b. 4:55 p. m., e. d. n.; amount, 0.10 inch. Variable positive in the a. m.; no negative observed during the day.
Feb. 14	Lt. rain b. 12:10 p. m., changed to sleet 2:45, e. 4:30 p. m., 0.12 inch. Steady positive from 9 to 11 a. m., began falling slowly; changed to negative at 12:05 p. m. Variable positive and negative from 12:05 to 3:45 p. m.; then changed to positive.
Feb. 15	A trace of snow b. d. n., e. 12:20 p. m. First observation at 9 a. m.; no negative observed; positive at all regular observations.
Feb. 24	Lt. rain 8:30 to 8:55 a. m.; hy. rain from 10:57 to 11 a. m.; lt. rain from 11 a. m. to 1:20 p. m.; hy. rain from 3:05 to 5:56 p. m.; thunder-storm from 2:50 to 5:53 p. m. Positive from 9 to 10 a. m.; negative at 10:55 a. m. Variable positive and negative with sparks during the hy. rain from 10:55 a. m. to 1 p. m. No observations from 1 to 3:20 p. m. Variable positive and negative from 3:20 to 6:40 p. m. Sparks during the thunder storm.
Feb. 25	Trace of snow b. d. n., e. 8:50 a. m. Positive at 9 a. m.; variable positive and negative from 10 to 11 a. m. A trace of snow mist from 11:30 a. m. to 8 p. m. Variable positive, with sparks, during the snow from 2 to 4 p. m. West gale winds.

TABLE L.—*Potential on days on which precipitation occurred at the place of observation, Terre Haute, Ind., March* 30, 1887, *to August* 25, 1888—Continued.

Date.	Remarks.
1888.	
Feb. 27	A trace of snow from 1:30 to 8 p. m. No special observations; positive at all regular observations; higher at 3 p. m. than at any other time.
Mar. 1	Potential positive 60 to 200 volts from 9 to 10 a. m.; then rose to a maximum of 800 volts at 10:10 a. m.; then fell gradually to —25 volts at 10:28 a. m.; then varied from 60 to 600 volts until 1 p. m. No special observations in the afternoon; 600 volts at 3 and 400 at 5 p. m.; lt. rain from 7:30 to 8 p. m., 0.14 inch; no observations after 5 p. m.
Mar. 5	A trace of snow from d. n. to 9:30 a. m.; first observation at 9 a. m.; no negative observed.
Mar. 6	A trace of snow b. d. n., e. 11:42 a. m.; negative at 10:45 and 11:20 a. m.; positive the rest of the time after 9 a. m.
Mar. 10	Lt. rain b. 1:45 a. m., e. 8:50 a. m.; variable positive and negative from 9 to 10 a. m.; lt. rain b. 3:40 p. m., changed to snow at 9, e. 9:45. p. m., 0.23 inch. No observations from 1 to 4:30 p. m. Variable positive and negative from 4:30 to 6:30 p. m.; no observations after that.
Mar. 16	Lt. rain b. 7:45, e. 7:50 a. m. Variable positive and negative from 9 to 10 a. m.; positive from 10 to 11 a. m. Lt. rain from 11:26 a. m. to 12:40 p. m., 0.29 inch. Negative for a few minutes at 11:45 a. m.
Mar. 19	Positive 150 volts at 9 a. m.; 30 at 11 a. m.; 50 at 1 p. m. No observations from 1 to 3 p. m. Lt. rain b. 2:10 p. m., continued all afternoon and evening. Variable positive and negative; generally negative all afternoon from 3 to 6:30 p. m. Amount of rain, 0.12 inch.
Mar. 20	Rain continued all night e. 11:07 a. m., 0.67 inch. Low potential; variable positive and negative from 10 a. m. to 12:15 p. m.
Mar. 23	No special observations; positive at all regular observations. Lt. snow mist b. 11:45 a. m., changed to sleet 3:50, e. 4:30 p. m. Potential low; 9 a. m., 60 volts; 11 a. m., 50; 1 p. m., 30; 3 p. m., 400; 5 p. m., 60.
Mar. 27	Lt. rain b. 7:50, e. 10:15 a. m. First observation at 8:30 a. m. Variable positive and negative from 8:30 to 10 a. m.; then positive from 11:30 a. m. to 12:30 p. m.; then variable positive and negative until 1:10 p. m. No observations after this. Lt. rain b. 3:30 p. m., continued all afternoon and evening.
Apr. 5	Cloudy in a. m.; low steady positive up to 4 p. m. Began to threaten at 3 p. m.; thunder and lightning b. 4:30 p. m. was very heavy from 5 to 6:30 p. m., e. 7 p. m.; hy. rain b. 5:57, e. 7:15 p. m., 0.77 inch. High positive from 4 to 5:30 p. m., with sparks; negative from 5:31 to 5:45 p. m.; variable positive and negative, often sparking, from 5:45 to 7 p. m., the last observation.
Apr. 9	Lt. rain b. 7:15 a. m., e. 4:50 p. m., 0.72 inch. Variable positive and negative all day from 9 a. m. to 5 p. m., generally negative.
Apr. 10	Hy. rain b. d. n, e. 9:30 a. m., 1.70 inches. Variable positive and negative from 9 to 11:45 a. m.
Apr. 21	Lt. rain mist from 2:15 to 7:25 p. m., 0.13 inch. Positive in a. m.; no observations from 1 to 3 p. m.; 30 volts at 3 p. m.; occasional drops of rain; no observations after 3 p. m.
Apr. 30	Lt. rain b. d. n., e. 11:15 a. m., 0.41 inch. Variable positive and negative from 9 to 10:30 a. m.; positive from 11 a. m. to 3 p. m.; negative at 5 p. m. Lt. rain from 5:20 to 8 p. m., 0.01 inch; no observation during the rain.
May 3	Variable positive and negative from 12:30 to 5:30 p. m. A trace of rain from 9 to 9:15 p. m. and from 10:40 to 11 p. m.; no observations after 5:30 p. m.
May 7	Lt. rain b. 8:15, e. 9:40 a. m. Negative at 9 a. m.; positive at 11 a. m. and at 1 and 3 p. m.; negative from 4:31 to 4:53 p. m.; variable positive and negative from 4:53 to 5:30 p. m. Lt. rain from 4:35 to 4:58 p. m., 0.13 inch. Lt. rain b. 11:30 p. m., e. d. n.
May 11	Variable positive and negative from 1 to 3 p. m. No observations after 3 p. m. Rain from 8:45 p. m. to d. n., 0.46 inch.
May 25	Hy. rain and thunderstorm d. n.; lt. rain from 9 to 11:20 a. m., 1.70 inches. Negative at 9 a. m.; positive at 11 a. m. and at 1, 3, and 5 p. m. Lt. rain from 3:10 to 3:15 p. m. and from 3:50 to 4:15 p. m. No observations from 1 to 3 p. m., nor during the rain.
June 1	A trace of rain from 1:15 to 1:20 p. m. No observations between 1 and 3 p. m.; positive at both those hours.
June 8	Positive from 9 a. m. to 3 p. m.; variable positive and negative from 4:50 to the last observation at 6:30 p. m. Threatening 5:30 p. m.; thunderstorm from 5:35 to 7:20 p. m.; a trace of rain from 7:05 to 7:20 p. m. and from 8:30 to 9:10 p. m.
June 9	Lt. rain b. 8:25, e. 11:10 a. m.; b. 12:20, e. 1:50 p. m. Low potential; negative at 9 and 11 a. m.; no special observations.
June 15	Variable positive and negative from 10:30 a. m. to 1 p. m.; no observations from 1 to 3 p. m.; positive at 3 and 5 p. m. Thunderstorm from 10:55 a. m. to 3:20 p. m.; lt. rain from 3:05 to 3:30 p. m., 0.09 inch; no negative observed during rain.
June 21	Lt. rain from 8 to 8:20 a. m. Negative from 9 to 10 a. m. Hy. rain b. 9:35, e. 11:35 a. m; distant thunder from 10 to 11 a. m. Variable positive and negative from 10 a. m. to 12 m. Amount of rain, 0.56 inch.
June 22	No observations before 4 p. m. Threatening and negative from 4 to 5:20 p. m. Variable positive and negative from 5:20 to 6 p. m. Lt. rain from 4:45 to 6:30 p. m.
June 23	Hy. rain from 2:45 to 3:35 p. m. and from 5:05 to 7:30 p. m., 0.92 inch. Low potential; positive at 9 and 11 a. m. and 1 p. m.; no observations from 1 to 3:30 p. m.; positive at 3:30 and 5 p. m.; no special observations.
June 26	Lt. rain b. d. n., e. 8:15 a. m. Low positive from 9:30 a. m. to 1 p. m.; threatening at 4 p. m.; variable positive and negative from 4 to 4:45 p. m.; lt. rain from 4:27 to 4:53 p. m.; distant thunder at 4:46 p. m.

TABLE L.—*Potential on days on which precipitation occurred at the place of observation, Terre Haute, Ind., March* 30, 1887, *to August* 25, 1888—Continued.

Date.	Remarks.
1888.	
June 27	Hy. rain d. n., e. 9:20 a. m.; b. 11:50 a. m., e. 9 p. m., 3.36 inches. Positive at 9 a. m.; negative at 11 a. m.; variable positive and negative from 12 m. to 6:20 p. m.
July 9	Rained hard during the night; lt. rain b. 8:50, e. 9:15 a. m. Negative at 9 a. m.; variable positive and negative from 9 to 10 a. m.; positive at 11 a. m. and 1 p. m.; no observations between 1 and 3 p. m.; negative at 3 and 5 p. m. Hy. rain from 1:45 to 3:10 p. m. Amount of rain last night and to-day, 1.69 inches.
July 14	Lt. rain mist b. 11:40 a. m., e. 3:30 p. m.; b. 8, e. 8:15 p. m., 0.04 inch. No special observations; positive at all regular observations; varied from 5 to 250 volts.
July 17	Variable positive and negative from 9 to 10 a. m. Lt. rain from 10:08 a. m. to 2:05 p. m. and from 3:45 to 6:50 p. m. High positive from 10 a. m. to 12 m.; variable positive and negative from 3:40 to 5:30 p. m. Amount of rain, 0.30 inch.
July 23	Threatening at 10 a. m. Variable positive and negative from 10:15 to 10:30 a. m.; then positive until 12 m. Thunderstorm from 2:30 to 3:40 p. m.; lt. rain from 2:56 to 3:35 p. m., 0.09 inch. No observations from 1 to 2:40 p. m.; variable positive and negative from 2:40 to 5:30 p. m.
July 26	Threatening at 9 a. m. Negative at 9:50 a. m.; variable positive and negative until 10 a. m. A trace of rain from 10 to 10:10 a. m. Positive from 10 a. m. to 12 m. Threatening, with variable positive and negative, from 5 to 6 p. m.
July 28	Threatening at 12 m. Negative at 12:20 to 12:25 p. m. Thunder and lightning from 12:28 to 4:30 p. m. Positive at 12:28 p. m.; negative from 12:29 to 12:48 p. m.; then variable positive and negative until 1:30 p. m.; no observations after this. Hy. rain from 12:33 to 3:15 p. m., 0.56 inch.
Aug. 4	Negative from 9:40 to 9:45 a. m. Lt. rain from 10:01 to 11 a. m., 0.13 inch. Thunderstorm from 10:16 to 11:25 a. m. Variable positive and negative from 10 to 11 a. m.; positive after 1 p. m.
Aug. 12	Lt. rain b. 10:30, e. 11:13 a. m., 0.05 inch. First observation at 10:50 a. m.; negative from 10:50 to 11:02 a. m.; then variable positive and negative until 11:30 a. m.; then positive.
Aug. 16	Lt. rain mist from 12:40 to 4:10 p. m., from 4:38 to 7 p. m., and from 8:15 to 9:45 p. m., 0.09 inch. No negative observed; varied from 50 to 350 volts in the forenoon and from 10 to 200 in the afternoon; no observations after 5 p. m.
Aug. 20	Rained very hard during the night, e. 3:50 p. m., 2.37 inches. Negative from 9:20 to 11:30 a. m.; positive at 9 a. m., and after 1 to 6 p. m.
Aug. 21	Rain b. d. n., e. 9:30 a. m., 0.45 inch. Variable positive and negative from 9 to 9:20 a. m.; threatening at 5 p. m., with negative.
Aug. 25	Clear, with variable positive and negative, from 9 to 10 a. m.; low positive all morning. Threatening at 4 p. m.; lt. rain from 4:06 to 4:28 p. m., 0.03 inch; distant thunder from 4:15 to 4:40 p. m. Negative from 4:20 to 4:25 p. m.; insulation poor.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative observed.	No observation.	Negative.	No negative.		
1887.										
Apr. 1	6 a. m	9:30 a. m	1				1			Lt. rain and sleet.
Apr. 1	11:56 a. m	12 m		½			1		1	Lt. rain; threatening after rain.
Apr. 6	During night.			10		1				Lt. rain.
Apr. 16	11 a. m	11:02 a. m			1			1		Lt. snow, tr.; dry snow.
Apr. 18	D. n	4 p. m	1				1			Rain, sleet, and snow.
Apr. 20	7 a. m	10:44 a. m	1				1			Lt. rain, 0.03 inch.
Apr. 20	7 p. m	7:15 p. m			1		1			Trace of rain; no obs. before.
Apr. 21	5:15 p. m	D. n		¾			1			Hy. rain.
Apr. 22	D. n	11:34 a. m	1				1			Hy. rain and thunderstorm; NW. gale; sparks.
Apr. 22	6:37 p. m	6:38 p. m		1				1		Lt. rain, tr.; sparks.
Apr. 22	7:20 p. m	8 p. m		¼		1				Lt. rain, thunder, 0.01 inch; sparks.
Apr. 28	2:55 p. m	2:56 p. m			1	1				Lt. rain, tr.
May 1	11 a. m	11:08 a. m	1			1			1	Lt. rain and hail, 0.02 inch; thunder.
May 2	12:53 p. m	1 p. m		1			1			Lt. rain; thunder.
May 5	D. n	10:50 a. m	1				1			Lt. rain.
May 5	2 p. m	2:10 p. m		3		1				Hy. rain.
May 5	5:20 p. m	6:30 p. m		¼			1			Lt. rain; thunder; sparks.
May 6	8 p. m	9 p. m		5		1				Lt. rain.
May 11	3:45 p. m	4:30 p. m		¾			1			Lt. rain; thunder; sparks.

TABLE L.—*Potential on days on which precipitation occurred at the place of observation, Terre Haute, Ind., March* 30, 1887, *to August* 25, 1888—Continued.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative observed.	No observation.	Negative.	No negative.		
1887.										
May 17	11:31 a. m.	1:05 p. m.	....	....	1	....	....	1	....	Lt. rain, tr.; mist.
May 21	1:30 p. m.	2:40 p. m.	....	4	....	....	1	....	....	Hy. rain; thunder; sparks.
May 24	5 p. m.	5:05 p. m.	....	2	....	....	1	....	....	Lt. rain, tr.; thunder.
May 30	D. n.	9:30 a. m.	1	....	....	....	1	....	....	Lt. rain.
May 30	7:30 p. m.	8:30 p. m.	....	9	....	1	....	....	....	Lt. rain; thunder.
May 31	1:41 p. m.	3:06 p. m.	....	¾	....	....	1	....	....	Hy. rain; thunder; sparks.
June 5	3:30 p. m.	4:59 p. m.	....	½	....	....	1	....	....	Hy. rain, 0.04 inch.
June 9	2 p. m.	2:01 p. m.	....	....	1	1	....	....	....	Lt. rain, tr.
June 20	1:30 p. m.	1:40 p. m.	....	2	....	....	1	....	....	Do.
June 22	1 p. m.	1:02 p. m.	....	2	....	....	1	....	1	Do.
June 30	1:25 p. m.	2 p. m.	....	1	....	1	....	....	....	Do.
June 30	4:26 p. m.	4:42 p. m.	....	¼	....	....	1	....	....	Do.
July 2	7:06 p. m.	7:07 p. m.	....	3	....	....	1	....	....	Lt. rain, tr.; thunder.
July 3	10:45 a. m.	10:46 a. m.	1	....	....	1	....	....	....	Lt. rain, tr.
July 4	3:48 p. m.	4:20 p. m.	....	¾	....	....	1	....	....	Lt. rain; thunder.
July 6	5:19 p. m.	5:55 p. m.	....	7	....	....	1	....	....	Lt. rain; thunder; sparks.
July 8	4:46 p. m.	5:45 p. m.	....	1	....	....	1	....	....	Do.
July 18	1:50 p. m.	2 p. m.	....	....	1	1	....	....	....	Lt. rain, tr.
July 18	5:15 p. m.	5:16 p. m.	....	3	....	....	1	....	....	Lt. rain, tr.; thunder.
July 21	3:31 p. m.	3:35 p. m.	....	¼	....	....	1	....	....	Lt. rain; thunder.
July 21	5:50 p. m.	7:05 p. m.	....	2	....	....	1	....	....	Hy. rain; thunder.
July 22	5:15 p. m.	5:50 p. m.	....	5	....	....	1	....	....	Lt. rain; sparks.
Aug. 4	2:20 p. m.	2:25 p. m.	....	....	1	1	....	....	....	Lt. rain, tr.; thunder
Aug. 4	4:14 p. m.	5:35 p. m.	....	2	....	....	1	....	1	Hy. rain; thunder.
Aug. 5	2:15 p. m.	3:40 p. m.	....	1	....	....	1	....	....	Lt. rain; thunder.
Aug. 11	8:25 a. m.	9:29 a. m.	1	....	....	....	1	....	....	Do.
Aug. 11	9 p. m.	12 mid.	....	10	....	1	....	....	....	Hy. rain; thunder.
Aug. 17	8:40 a. m.	12:35 p. m.	1	....	....	....	....	1	....	Lt. rain, mist.
Aug. 21	3:45 p. m.	3:49 p. m.	....	....	1	1	....	....	....	Lt. rain, tr.
Aug. 22	D. n.	9:45 a. m.	1	....	....	....	....	1	....	Lt. rain.
Sept. 22	1 p. m.	2:45 p. m.	....	....	1	1	....	....	....	Lt. rain, tr.
Sept. 26	12:10 p. m.	D. n.	....	....	1	....	1	....	....	Lt. rain, mist.
Sept. 27	All day.		1	....	....	....	1	....	....	Do.
Sept. 29	4:04 p. m.	5:48 p. m.	....	....	1	....	1	....	....	Hy. rain; thunder.
Sept. 30	9:37 a. m.	9:38 a. m.	....	....	1	....	....	1	1	Lt. rain, tr.
Oct. 10	D. n.	1:50 p. m.	1	....	....	....	1	..	....	Lt. rain.
Oct. 10	4:02 p. m.	4:10 p. m.	....	2	....	....	1	....	....	Do.
Oct. 11	4:08 p. m.	5:48 p. m.	....	....	1	....	1	....	....	Hy. rain; sparks.
Oct. 20	10:50 a. m.	10:55 a. m.	....	....	1	....	....	1	1	Lt. rain tr.; NW. gale.
Oct. 23	1:10 p. m.	2:15 p. m.	....	1	....	1	....	....	....	Lt. rain.
Nov. 9	4 p. m.	D. n.	....	7	....	1	....	....	....	Do.
Nov. 19	8:30 a. m.	9:25 a. m.	1	....	....	....	1	....	1	Lt. snow, tr.; W. gale; cold wave.
Nov. 23	7:50 a. m.	D. n.	1	....	....	....	1	....	....	Hy. rain, 1.08 inches.
Nov. 25	D. n.	2:50 p. m.	1	....	....	....	1	....	....	Lt. rain.
Nov. 26	All day.		1	....	....	....	1	....	....	Do.
Dec. 2	All day.		1	....	....	....	1	....	....	Do.
Dec. 3	D. n.	1:05 p. m.	1	....	....	...	1	....	....	Lt. rain, 0.55 inch.
Dec. 7	7 a. m.	1:30 p. m.	1	....	....	....	1	....	....	Lt. rain, 0.07 inch.
Dec. 9	9:10 a. m.	4:50 p. m.	....	....	1	....	....	1	....	Lt. rain, 0.03 inch; no sp. obs.
Dec. 10	All day.		1	....	....	....	....	1	....	Lt. rain, 0.72 inch; no sp. obs.
Dec. 15	6 a. m.	4:15 p. m.	1	....	....	....	1	....	....	Lt. snow, tr.
Dec. 20	6 a. m.	9:15 p. m.	1	....	....	....	1	....	....	Rain and snow; sparks; cold wave.
Dec. 23	11:30 a. m.	11:45 a. m.	....	....	1	1	....	....	....	Lt. snow, tr.
Dec. 26	8:50 a. m.	9:30 a. m.	1	....	....	...	....	1	....	Do.
Dec. 30	1:10 p. m.	D. n.	....	....	1	....	....	1	....	Lt. snow; sparks.
Dec. 31	D. n.; all day.		1	....	....	....	1	....	...	Lt. rain.
1888.										
Jan. 5	10:15 a. m.	6:15 p. m.	....	1	....	....	1	....	....	Lt. rain, 0.02 inch; fog.
Jan. 6	All day.		1	....	....	....	1	....	....	Hy. rain, 1.16 inches.
Jan. 7	All day.		1	....	....	....	1	....	....	Lt. rain.
Jan. 9	D. n.	10 a. m.	1	....	....	....	....	1	....	Lt. snow, tr.
Jan. 9	4 p. m.	D. n.	....	....	1	....	1	....	....	Lt. snow; almost ice.
Jan. 12	12:05 p. m.	D. n.	....	....	1	....	1	....	....	Snow, sleet, and rain.
Jan. 17	11:05 a. m.	5:30 p. m.	....	....	1	....	....	1	....	Lt. snow, tr; sparks.
Jan. 25	D. n.	10:05 a. m.	1	....	....	....	....	1	....	Lt. snow, tr.
Jan. 30	3:30 p. m.	7 p. m.	....	....	1	....	....	1	....	Lt. rain, mist, 0.01 inch; no sp. obs.
Feb. 4	D. n.	8:50 p. m.	1	....	....	....	1	....	....	Lt. rain and snow.
Feb. 7	3:05 p. m.	6:50 p. m.	....	....	1	....	....	1	....	Lt. rain, mist, 0.01 inch.

TABLE L.—*Potential on days on which precipitation occurred at the place of observation, Terre Haute, Ind., March 30, 1887, to August 25, 1888*—Continued.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative observed.	No observation.	Negative.	No negative.		
1888.										
Feb. 8	4:55 p. m.	D. n.	----	----	1	----	----	1	----	Lt. snow, 0.10 inch.
Feb. 14	12:10 p. m.	4:30 p. m.	----	½	----	----	1	----	----	Lt. rain and sleet.
Feb. 15	D. n.	12:20 p. m.	1	----	----	----	----	1	----	Lt. snow, tr.
Feb. 24	10:57 a. m.	5:56 p. m.	----	½	----	----	1	----	----	Hy. rain; thunder; sparks.
Feb. 25	11:30 a. m.	8 p. m.	----	2	----	----	----	1	----	Lt. snow, tr.; sparks.
Feb. 27	1:30 p. m.	8 p. m.	----	----	1	----	----	1	----	Lt. snow, tr.; no sp. obs.
Mar. 1	7:30 p. m.	8 p. m.	----	9	----	1	----	----	----	Lt. rain, 0.14 inch.
Mar. 5	D. n.	9:30 a. m.	1	----	----	----	----	1	----	Lt. snow, tr.
Mar. 6	D. n.	11:42 a. m.	1	----	----	----	1	----	----	Do.
Mar. 10	3:40 p. m.	9:45 p. m.	----	6	----	----	1	----	----	Lt. rain.
Mar. 16	11:26 a. m.	12:40 p. m.	----	3	----	----	1	----	----	Lt. rain, 0.29 inch.
Mar. 19	2:10 p. m.	D. n.	----	----	1	----	1	----	----	Lt. rain, 0.12 inch; no sp. obs. b.
Mar. 20	D. n.	11:07 a. m.	1	----	----	----	1	----	----	Lt. rain, 0.67 inch.
Mar. 23	11:45 a. m.	4:30 p. m.	----	----	1	----	----	1	----	Lt. snow and sleet.
Mar. 27	7:50 a. m.	10:15 a. m.	1	----	----	----	1	----	----	Lt. rain.
Mar. 27	3:30 p. m.	D. n.	----	4	----	1	----	----	----	Do.
Apr. 5	5:57 p. m.	7:15 p. m.	----	½	----	----	1	----	----	Hy. rain; thunder; 0.77 inch; sparks.
Apr. 9	7:15 a. m.	4:50 p. m.	1	----	----	----	1	----	----	Lt. rain, 0.72 inch.
Apr. 10	D. n.	9:30 a. m.	1	----	----	----	1	----	1	Hy. rain, 1.70 inches.
Apr. 21	2:15 p. m.	7:25 p. m.	----	----	1	----	----	1	----	Lt. rain, mist, tr.; no. sp. obs.
Apr. 30	D. n.	11:15 a. m.	1	----	----	----	1	----	----	Lt. rain.
Apr. 30	5:20 p. m.	8 p. m.	----	½	----	1	----	----	----	Lt. rain, 0.01 inch.
May 3	9 p. m.	11 p. m.	----	9	----	1	----	----	----	Lt. rain, tr.
May 7	8:15 a. m.	9:40 a. m.	1	----	----	----	1	----	----	Lt. rain.
May 7	4:35 p. m.	4:58 p. m.	----	½	----	----	1	----	1	Do.
May 11	8:45 p. m.	D. n.	----	8	----	1	----	----	----	Lt. rain, 0.46 inch.
May 25	D. n.	4:15 p. m.	1	----	----	----	1	----	----	Hy. rain, 1.70 inches; thunder.
June 1	1:15 p. m.	1:20 p. m.	----	----	1	1	----	----	----	Lt. rain, tr.
June 8	7:05 p. m.	9:10 p. m.	----	2	----	1	----	----	----	Lt. rain, tr.; thunder.
June 9	8:25 a. m.	1:50 p. m.	1	----	----	----	----	----	----	Lt. rain.
June 15	3:05 p. m.	3:30 p. m.	----	5	----	1	----	----	----	Lt. rain, 0.09 inch; thunder.
June 21	9:35 a. m.	11:35 a. m.	----	½	----	----	1	----	1	Hy. rain, 0.56 inch; thunder.
June 22	4:45 p. m.	6:30 p. m.	----	¾	----	----	1	----	----	Lt. rain.
June 23	2:45 p. m.	7:30 p. m.	----	----	1	----	----	1	----	Hy. rain; no sp. obs.
June 26	4:27 p. m.	4:53 p. m.	----	½	----	----	1	----	----	Lt. rain; thunder.
June 27	D. n.	9 p. m.	1	----	----	----	1	----	----	Hy. rain, 3.36 inches.
July 9	D. n.	9:15 a. m.	1	----	----	----	1	----	----	Hy. rain, 1.69 inches.
July 9	1:45 p. m.	3:10 p. m.	----	4	----	----	1	----	----	Do., 1.69 inches.
July 14	11:40 a. m.	8:15 p. m.	----	----	1	----	1	----	1	Lt. rain mist, 0.04 inch; no. sp. obs.
July 17	10:08 a. m.	2:05 p. m.	----	1	----	----	1	----	----	Lt. rain.
July 17	3:45 p. m.	6:50 p. m.	----	¼	----	----	1	----	----	Hy. rain, 0.30 inch.
July 23	2:56 p. m.	3:35 p. m.	----	4	----	----	1	----	1	Lt. rain. 0.09 inch; thunder.
July 26	10 a. m.	10:10 a. m.	----	1	----	----	----	1	1	Lt. rain, tr.
July 28	12:33 p. m.	3:15 p. m.	----	¼	----	----	1	----	----	Hy. rain, 0.56 inch; thunder.
Aug. 4	10:01 a. m.	11 a. m.	----	¼	----	----	1	----	----	Lt. rain 0.13 inch; thunder.
Aug. 12	10:30 a. m.	11:13 a. m.	1	----	----	----	1	----	1	Lt. rain, 0.05 inch.
Aug. 16	12:40 p. m.	9:45 p. m.	----	----	1	----	----	1	----	Lt. rain mist, 0.09 inch; no sp. obs.
Aug. 20	D. n.	3:50 p. m.	1	----	----	----	1	----	----	Hy. rain 2.37 inches.
Aug. 21	D. n.	9:30 a. m.	1	----	----	----	1	----	1	Lt. rain, 0.45 inch.
Aug. 25	4:06 p. m.	4:28 p. m.	----	7	----	----	1	----	----	Lt. rain, 0.03 inch; thunder.
Total (136)			46	59	31	26	83	27	15	

SUMMARY.

Number of days.	Precipitation.	Before.			During.			Negative after.
		No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.	
(50)	Rain	9	30	11	14	31	5	4
(2)	Rain and sleet	2	0	0	0	2	0	0
(1)	Rain and hail	1	0	0	1	0	0	1
(1)	Snow	0	0	1	0	0	1	0

TABLE M.—*Potential on days on which precipitation occurred, New Haven, Conn., August* 1, 1886, *to July* 30, 1887.

[Extracts from daily journal.]

Date.	Remarks.
1886.	
July 30	Light rain at 9 a. m.; potential variable negative at 9 a. m.; positive at other hours of observation.
July 31	Light rain at 9 a. m.; potential positive at all observations.
Aug. 2	Light rain 12:25 to 12:58 p. m.; potential low positive at 9 and 11 a. m., zero at 1 p. m., and high positive at 3 p. m.
Aug. 7	Light rain at 1 and 3 p. m.; potential positive at 9, 11 a. m., and 1 p. m.; negative at 3 p. m.
Sept. 23	Light rain about 9:08 a. m.; potential high positive at 9 a. m.; low positive at 11 a. m.; high positive at 1 and 3 p. m.
Oct. 18	Heavy rain at 9 a. m.; potential variable from negative to positive at 9 a. m.; positive at other observations.
Oct. 21	Light sprinkling rain at 11 a. m.; potential positive at 9, 11 a. m., and 1 p. m.; negative at 3 p. m.
Oct. 27	Light rain at 9, 11 a. m., and 1 p. m.; potential high negative at 9 a. m.; positive at 11 a. m. and 1 p. m.
Oct. 28	Light rain at 3 p. m.; potential positive at all observation hours.
Nov. 6	Light rain 9:38 to 11 a. m.; potential variable from positive to negative at 11 a. m.; positive at all other hours of observation.
Nov. 10	Light rain at 11 a. m. and 1 p. m.; potential negative at 11 a. m.; variable from positive to negative at 1 p. m.; high positive at 9 a. m. and 3 p. m.
Nov. 12	Light rain from 1:03 to 3 p. m.; potential high negative at 3 p. m.; positive at other observations.
Nov. 17	Light rain all day; potential variable from positive to negative at 9 a. m.; high positive at other observations.
Nov. 18	Light rain at 11 a. m.; potential variable positive to negative at 11 a. m.; positive at other observations.
Nov. 23	Light rain at 9, 11 a. m., and 1 p. m.; potential high negative at 9 a. m.; positive at other observations.
Nov. 25	Light rain 6 to 8 a. m. and at 3 p. m.; potential positive at all observations.
Dec. 7	Light snow at 11 a. m.; heavy snow at 3 p. m.; potential negative at 9 and 11 a. m.; positive at 1 and 3 p. m.
Dec. 13	Light rain all day; potential high negative at 1 p. m.: normal (positive) at 9, 11 a. m., and 3 p. m.
Dec. 15	Light rain at 11 a. m., 1 and 3 p. m.; potential positive at 9 and 11 a. m.; negative at 1 and 3 p. m.
Dec. 16	Light snow at 9, heavy snow at 11 a. m.; potential high positive all day.
Dec. 18	Light rain all day; potential negative at 9 and 11 a. m.; positive at 1 p. m.
Dec. 24	Dense fog at 9 and 11 a. m.; light rain at 1 p. m.; potential positive at all observations.
Dec. 27	Light snow at 9 and 11 a. m.; potential positive at all observations.
Dec. 30	Light snow all day from 1:15 a. m.; potential high positive at all observations.
Dec. 31	Snow of 30th turned to sleet at 6 a. m. to-day; sleet turned to rain at 4 p. m.; potential high negative all day.
1887.	
Jan. 1	Light rain continued until 1 p. m.; potential negative at 11 a. m.; positive at other observations.
Jan. 5	Light snow 2:10 p. m. to 2:30 p. m.; potential positive at all observations.
Jan. 14	Light rain 1:35 a. m. to 2 p. m.; potential negative at 9 a. m.; positive at other observations.
Jan. 15	Light snow at intervals from 9:25 a. m. until 6 p. m.; potential positive all day.
Jan. 17	Light rain 7:25 a. m. until 6:55 p. m.; potential negative at 9 and 11 a. m.; positive at 1 and 3 p. m.
Jan. 24	Light rain from 8 a. m. to 6 p. m.; potential negative at 9 and 11 a. m. and 1 p. m.; positive at 3 p. m.
Jan. 26	Light rain 11:15 a. m. to 12:15 p. m.; light snow 12:15 to 6:30 p. m.; heavy snow about 3 p. m.; potential negative at 3 p. m.; positive at other observations.
Jan. 29	Heavy rain from 12:15 p. m. to during night; potential negative at 1 and 3 p. m.; positive at other hours of observation.
Feb. 2	Heavy snow from 7:10 a. m. to 12:30 p. m.; sleet from 4:15 to 5 p. m.; snow 5:30 p. m. to during night; potential high negative at 9 a. m.; high positive at other hours of observation.
Feb. 3	Light rain 12:15 to 5:30 p. m.; potential variable from positive to negative at 3 p. m.; positive at other hours of observation.
Feb. 7	Light rain 1:15 to 3 p. m.; sleet from 3 to 11 p. m.; potential negative at 9 a. m. and 3 p. m.; positive at 11 a. m. and 1 p. m.
Feb. 8	Light rain from 11 p. m. of 7th to 3:30 p. m. to-day, and from 6 to 9:30 p. m.; potential negative at 9 and 11 a. m.; positive at 1 and 3 p. m.
Feb. 11	Light rain 3:40 to 4:30 p. m.; potential positive at all observations.
Feb. 15	Rain from 1:50 a. m. to 1:15 p. m.; rainfall heavy at 9 a. m.; potential negative at 9 a. m.; positive at other observations.
Feb. 18	Light snow from 7:40 to 10:45 a. m.; light rain from 1 to 10:25 p. m.; potential negative at 9 a. m. and 3 p. m.; positive at 11 a. m. and 1 p. m.
Feb. 22	Heavy snow 7:20 to 10:30 a. m.; light rain 10:30 a. m. to 1 p. m.; potential negative at 11 a. m.; positive at other observations.

TABLE M.—*Potential on days on which precipitation occurred, New Haven, Conn., August* 1, 1886, *to July* 30, 1887—Continued.

Date.	Remarks.
1887.	
Feb. 24	Light rain 2:25 to 9:45 a. m.; potential positive at all observations.
Feb. 26	Heavy snow 10:20 a. m. to 6 p. m.; potential positive at all observations.
Mar. 1	Light snow 11 a. m. to 1 p. m.; potential positive at all observations.
Mar. 10	Rain 12:10 a. m. to 12:15 p. m., heavy at 9 a. m.; potential negative at 9 and 11 a. m.; positive at 1 and 3 p. m.
Mar. 22	Heavy snow 8:50 to 10:30 a. m.; light rain 11:20 a. m. to 1 p. m.; light snow 1 to 6 p. m. potential negative at 9 a. m.; positive at other observations.
Mar. 28	Light rain began 10:05 p. m. on 27th, ended 10:30 a. m. 28th; potential negative at 9 a. m.; positive at other observations.
Apr. 1	Light snow began 3:25 a. m., ended 3:10 p. m.; potential positive at all observations.
Apr. 2	Light snow began d. n., ended 6:05 p. m.; potential positive at all observations.
Apr. 15	Rain began 4:15 p. m. and continued during the night; potential negative at 3 p. m.; positive at other observations.
Apr. 18	Light snow began at 9:40 a. m., turned to sleet at 1:30 p. m.; sleet ended at 4:30 p. m.; potential negative at 8 and 11 a. m.; positive at 1 and 3 p. m.
Apr. 23	Light rain began 7 a. m. and continued during the day; thunder storm about 10 p. m.; potential positive at all observations.
Apr. 26	Light rain about 9:30 a. m.; potential negative at 7 a. m.; positive at other observations.
Apr. 28	Light rain 7 to 10:45 a. m.; potential negative at 7:10 a. m.; positive at other observations.
May 7	Light rain 3:40 to 4:45 p. m.; potential negative at 11 a. m. and 3 p. m.; positive at 7 a. m. and 1 p. m.
May 21	Light rain 11:30 a. m. to 1:50 p. m.; potential negative at 1 and 3 p. m.; positive at 7 and 11 a. m.
May 25	Light rain 4 to 7 a. m.; potential positive at all observations.
June 1	Heavy rain 12:01 a. m. to 1:30 p. m.; potential negative at 7 and 11 a. m.; positive at 1 and 3 p. m.
June 2	Light rain 6 a. m. to 2:15 p. m.; potential positive at all observations.
June 7	Light rain 8:25 to 10 a. m.; potential positive at all observations.
June 8	Light rain 10:20 a. m. to 12 m.; potential positive at all observations.
June 18	Light rain 7:22 to 8:30 a. m.; potential positive at all observations.
June 22	Light rain 1:55 to 2:10 p. m.; potential positive at all observations.
June 23	Rain 6:55 a. m.; continued during the day; rainfall heavy at 11 a. m. and 3 p. m.; potential negative at 1 and 3 p. m.; positive at 7 and 11 a. m.
July 6	Light rain 12:05 to 9:45 a. m.; 12:30 to 1:50 p. m.; thunder storm from 5:20 to 6:05 p. m.; potential positive at all observations.
July 16	Light rain 6:30 to 7:45 a. m.; potential positive at all observations.
July 18	Heavy rain with thunder storm 12:45 to 1:20 p. m.; potential negative at 1 p. m.; positive at other observations.
July 21	Light rain 8:15 a. m. to 4:55 p. m.; rainfall heavy at 3 p. m.; potential negative at 3 p. m.; positive at other observations.
July 22	Rain from 7:05 p. m. on 21st to 9:30 a. m. to-day; heavy rain at 7 a. m.; potential negative at 7 a. m.; positive at other observations.
July 23	Light rain 12:50 to 1 p. m., and 3:20 p. m. and during night; potential positive at all observations.
July 25	Light rain 6:30 to 7:05 a. m.; potential positive at all observations.
July 26	Light rain with thunder storm 3:55 to 4:45 p. m.; potential positive at all observations.

SUMMARY.

During the year 72 storms, accompanied by precipitation, were noted, occurring between the hours of 7 a. m. and 3:30 p. m., the time covered by observations.

Light rain.—During 47 of the storms the precipitation consisted of light rain. In 23 of these the rainfall began before the first observation of the day; 3 were preceded by negative potentials and 21 by positive. No observations were made during 9 of them. Negative potentials occurred during 25 and positive during 13 of them. After precipitation negative potential was noted only once.

Heavy rain.—In 9 storms the precipitation consisted of heavy rain; 6 of these began before the first observation and 3 were preceded by positive potentials; negative potentials were noted during all of them.

Snow.—Snow was the precipitation during 14 of the 72 storms. Of these 14, 7 began before the first observation of the day; 2 were preceded by negative and 5 by positive potentials. Negative potentials were noted during 5, and only positive during 9 of them.

Sleet.—The precipitation during 2 storms consisted of sleet. Both began before the first observation and both were accompanied by negative potentials during precipitation.

TABLE M.—*Potential on days on which precipitation occurred, New Haven, Conn., August* 1, 1886, *to July* 30, 1887—Continued.

Date.	Precipitation.							Remarks.
	Before.			During.			Negative after.	
	No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.		
1886.								
July 30	1	.....	.....	.....	1	.....	.....	Lt. rain.
July 31	1	.....	.....	.....	.....	1	.....	Do.
Aug. 2	.....	.....	1	1	.....	.....	.....	Do.
Aug. 7	.....	.....	1	.....	1	.....	.....	Do.
Sept. 23	.....	.....	1	1	.....	.....	.....	Do.
Oct. 18	1	.....	.....	.....	1	.....	.....	Hy. rain.
Oct. 21	.....	.....	1	.....	.....	1	1	Sprinkling.
Oct. 27	1	.....	.....	.....	1	.....	.....	Lt. rain.
Oct. 28	.....	.....	1	.....	.....	1	.....	Do.
Nov. 6	.....	.....	1	.....	1	.....	.....	Do.
Nov. 10	.....	.....	1	.....	1	.....	.....	Do.
Nov. 12	.....	.....	1	.....	1	.....	.....	Do.
Nov. 17	1	.....	.....	.....	1	.....	.....	Do.
Nov. 18	.....	.....	1	.....	1	.....	.....	Do.
Nov. 23	1	.....	.....	.....	1	.....	.....	Do.
Nov. 25	.....	.....	1	.....	.....	1	.....	Do.
Dec. 7	.....	2	.....	.....	1	.....	.....	Lt. snow at 11 a. m; hy. at 3 p. m.
Dec. 13	1	.....	.....	.....	1	.....	.....	Lt. rain all day.
Dec. 15	.....	.....	1	.....	1	.....	.....	Lt. rain 11 a. m. to 3 p. m.
Dec. 16	1	.....	.....	.....	.....	1	.....	Lt. snow at 9 a. m.; hy. at 11 a. m.
Dec. 18	1	.....	.....	.....	1	.....	.....	Lt. rain all day.
Dec. 24	.....	.....	1	.....	.....	1	.....	Fog at 9 and 11 a. m; rain at 1 p. m.
Dec. 27	1	.....	.....	.....	.....	1	.....	Lt. snow at 9 a. m.
Dec. 30	1	.....	.....	.....	.....	1	.....	Lt. snow all day; began 1:15 a. m.
Dec. 31	1	.....	.....	.....	1	.....	.....	Sleet all day. Snow turned to sleet at 6 a. m; sleet to rain at 4 p. m.
1887.								
Jan. 1	1	.....	.....	.....	1	.....	.....	Lt. rain; ended 1 p. m.
Jan. 5	.....	.....	1	.....	.....	1	.....	Lt. snow.
Jan. 14	1	.....	.....	.....	1	.....	.....	Lt. rain.
Jan. 15	.....	.....	1	.....	.....	1	.....	Lt. snow.
Jan. 17	1	.....	.....	.....	1	.....	.....	Lt. rain.
Jan. 24	1	.....	.....	.....	1	.....	.....	Lt. rain; hy. rain.
Jan. 26	.....	.....	1	.....	1	.....	.....	Hy. snow.
Jan. 29	.....	.....	1	.....	1	.....	.....	Hy. rain.
Feb. 2	1	.....	.....	.....	1	.....	.....	Hy. snow.
Feb. 3	.....	.....	1	.....	1	.....	.....	Lt. rain.
Feb. 7	.....	4	.....	.....	1	.....	.....	Do.
Feb. 8	1	.....	.....	.....	1	.....	.....	Do.
Feb. 11	.....	.....	1	1	.....	.....	.....	Do.
Feb. 15	1	.....	.....	.....	1	.....	.....	Hy. rain.
Feb. 18	1	.....	.....	.....	1	.....	.....	Sleet.
Feb. 22	1	.....	.....	.....	1	.....	.....	Hy. snow, followed by rain.
Feb. 24	1	.....	.....	.....	.....	1	.....	Lt. rain.
Feb. 26	.....	.....	1	.....	.....	1	.....	Hy. snow.
Mar. 1	.....	.....	1	.....	.....	1	.....	Lt. snow.
Mar. 10	1	.....	.....	.....	1	.....	.....	Hy. rain; lt. rain.
Mar. 22	1	.....	.....	.....	1	.....	.....	Hy. rain.
Mar. 28	1	.....	.....	.....	1	.....	.....	Lt. rain.
Apr. 1	1	.....	.....	.....	.....	1	.....	Lt. snow.
Apr. 2	1	.....	.....	.....	.....	1	.....	Do.
Apr. 15	.....	$1\frac{1}{4}$	.....	1	.....	.....	.....	Rain.
Apr. 18	.....	$1\frac{2}{8}$	.....	.....	1	.....	.....	Lt. snow.
Apr. 23	1	.....	.....	.....	1	.....	.....	Lt. rain.
Apr. 26	1	.....	.....	.....	1	.....	.....	Do.
Apr. 28	1	.....	.....	.....	1	.....	.....	Do.
May 7	.....	5	.....	1	.....	.....	.....	Do.
May 24	.....	.....	1	.....	1	.....	.....	Do.
May 25	1	.....	.....	.....	.....	1	.....	Do.
June 1	1	.....	.....	.....	1	.....	.....	Hy. rain.
June 2	1	.....	.....	.....	.....	1	.....	Lt. rain.
June 7	.....	.....	1	1	.....	.....	.....	Do.
June 8	.....	.....	1	.....	.....	1	.....	Do.
June 18	.....	.....	1	1	.....	.....	.....	Do.

TABLE M.—*Potential on days on which precipitation occurred. New Haven, Conn., August* 1, 1886, *to July* 30, 1887—Continued.

Date.	Precipitation.							Remarks.
	Before.			During.			Negative after.	
	No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.		
1887.								
June 22	.....	.....	1	1	.....	.....	.....	Lt. rain.
June 23	1	.....	.....	.....	1	.....	.....	Lt. rain; hy. rain.
July 6	1	.....	.....	.....	.....	1	.....	Lt. rain.
July 16	1	.....	.....	.....	.....	1	.....	Do.
July 18	1	.....	.....	.....	1	.....	.....	Hy. rain; t. s.
July 21	.....	.....	1	.....	1	.....	.....	Do.
July 22	.....	.....	1	.....	1	.....	.....	Do.
July 23	.....	.....	1	.....	.....	1	.....	Lt. rain.
July 25	1	.....	.....	.....	.....	1	.....	Do.
July 26	.....	.....	1	1	.....	.....	.....	Do.; t. s.

SUMMARY.

Remarks.	Precipitation.						
	Before.			During.			Negative after.
	No observation.	Negative first observed.	No negative.	No observation.	No negative.	Negative.	
Light rains	23	3	29	9	25	13	1
Heavy rains	6	0	3	0	9	0	0
Total rains	29	3	24	9	34	13	1
Snow	7	2	5	0	5	9	0
Sleet	2	0	0	0	2	0	0
Total (72)	38	5	29	9	41	22	1

TABLE N.—*The potential on days on which precipitation occurred at Columbus, Ohio, March* 1, 1886, *to July* 28, 1888.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.		
1886.										
Mar. 12	7 p. m.	D. n.	....	4	....	1	....	....	....	Lt. snow.
Apr. 6	D. n.	3 p. m.	1	....	..	....	1	....	....	Do.
Apr. 26	4 p. m.	D. n.	....	5	....	1	....	....	....	Lt. rain.
Apr. 29	6 p. m.	D. n.	....	3	....	1	....	....	....	Do.
May 4	Late p. m.	D. n.	....	7	....	1	....	....	....	Do.
May 5	D. n.	2 p. m.	1	....	....	....	1	....	....	Do.
May 10	Late p. m.	D. n.	....	7	....	1	....	....	....	Hy. rain, thunder.
May 11	Late p. m.	D. n.	....	7	....	1	....	....	....	Do.
May 12	Late p. m.	D. n.	....	7	....	1	....	....	....	Do.
May 14	Late p. m.	D. n.	....	6	....	1	....	....	....	Do.
May 25	7 p. m.	D. n.	....	8	....	1	....	....	....	Do.

TABLE N.—*The potential on days on which precipitation occurred at Columbus, Ohio, March* 1, 1886, *to July* 28, 1888—Continued.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.		
1886.										
May 27	3 p. m.	5 p. m	....	1	....	....	1	....	....	Lt. rain, thunder.
July 9	10:25 p. m.	D. n.	....	9	....	1	....	....	....	Lt. rain.
July 12	11 p. m.	D. n.	....	10	....	1	....	....	....	Hy. rain, thunder.
July 13	7 ——	D. n.	....	4	....	1	....	....	....	Do.
July 14	Late p. m.	D. n.	....	8	....	1	....	....	....	Lt. rain.
July 15	D. n	10 a. m	1	....	....	....	1	....	....	Do.
July 20	3:20 p. m.	6 p. m	....	2	....	....	1	....	....	Do.
July 27	1:50 p. m.	2 p. m	....	3	....	....	1	....	....	Lt. rain, trace.
July 30	1:35 p. m.	2:20 p. m.	....	5	....	....	1	....	....	Hy. rain, 2.83 inches; thunder.
Sept. 10	2:40 p. m.	3:10 p. m.	....	....	1	....	....	1	....	Lt. rain.
Sept. 15	2 p. m.	D. n.	....	....	1	....	....	1	....	Do.
Sept. 22	6:40 p. m.	D. n.	....	4	....	1	....	....	....	Do.
Sept. 27	All day		1	....	....	....	1	....	....	Do.
Oct. 4	3 p. m.	3:30 p. m.	....	6	....	....	1	....	....	Trace of rain.
Oct. 26	Late p. m.	D. n.	....	8	....	1	....	....	....	Lt. rain.
Oct. 27	All day		1	....	....	....	1	....	....	Do.
Oct. 28	3 p. m.	5 p. m	....	2	....	....	....	1	....	Do.
Nov. 3	3 p. m.	——	....	....	1	....	....	1	....	Lt. rain, mist.
Nov. 10	All day		1	....	....	....	....	1	....	Do.
Nov. 12	D. n	10 a. m	1	....	....	....	....	1	....	Lt. snow.
Nov. 17	All day		1	....	....	....	....	1	....	Lt. rain, mist.
Nov. 22	All day		1	....	....	....	....	1	....	Do.
Nov. 23	All day		1	....	....	....	....	1	....	Do.
Nov. 30	9 a. m	11 a. m	1	....	....	....	....	1	....	Lt. snow.
Dec. 1	D. n	12 m	1	....	....	....	....	1	....	Lt. snow.
Dec. 13	All day		1	....	....	....	1	....	....	Lt. rain.
Dec. 17	All day		1	....	....	....	....	1	....	Lt. snow.
Dec. 22	All day		1	....	....	....	1	....	....	Do
Dec. 23	All day		1	....	....	....	1	....	....	Lt. rain.
Dec. 24	All day		1	....	....	....	1	....	....	Lt. rain and snow.
1887.										
Jan. 5	All day		1	....	....	....	....	1	....	Lt. snow.
Jan. 6	All day		1	....	....	....	....	1	....	Do.
Jan. 8	1 p. m.	3 p. m	....	....	1	....	....	1	....	Do.
Jan. 14	All day		1	....	....	....	1	....	....	Lt. rain.
Jan. 26	All day		1	....	....	....	....	1	....	Lt. snow.
Jan. 28	All day		1	....	....	....	1	....	....	Lt. rain.
Feb. 1	3 p. m.	——	....	....	1	....	....	1	....	Do.
Feb. 2	11 a. m	3 p. m	....	....	1	....	....	1	....	Lt. rain, thunder, high potential.
Feb. 3	All day		1	....	....	....	1	....	....	Lt. rain, mist.
Feb. 7	9 a. m	12 m	1	....	....	....	....	1	....	Do.
Feb. 8	3 p. m	D. n.	....	½	....	....	1	....	....	Lt. rain.
Feb. 10	1 p. m	D. n.	....	....	1	....	....	1	....	Lt. rain, mist.
Feb. 11	9 a. m	11 a. m	1	....	....	....	1	....	....	Do.
Feb. 14	All day		1	....	....	....	1	....	....	Do.
Feb. 15	All day		1	....	....	....	....	1	....	Do.
Feb. 18	10 a. m	11 a. m	....	....	1	1	....	....	....	Lt. rain
Feb. 21	11 a. m	11:10 a. m.	....	....	1	....	....	1	....	Do.
Feb. 23	All day		1	....	....	....	....	1	....	Lt. rain, mist.
Mar. 9	9 a. m	11 a. m	1	....	....	....	....	1	....	Lt. rain.
Mar. 14	9 a. m	11 a. m	1	....	....	....	....	1	....	Lt. snow.
Mar. 18	D. n.	10 a. m	1	....	....	....	....	1	....	Do.
Mar. 21	D. n.	10 a. m	1	....	....	....	....	1	....	Do.
Mar. 21	1 p. m	4 p. m	....	¼	....	....	1	....	....	Lt. rain.
Apr. 18	1 p. m	D. n.	....	2	....	....	1	....	....	Do.
Apr. 22	All day		1	....	....	....	1	....	....	Hy. rain, thunder.
May 5	6 p. m	D. n.	....	3	....	1	....	....	....	Do.
May 31	11 a. m	11:10 a. m.	....	....	1	....	....	1	....	Lt. rain.
June 1	11 a. m	12 m	....	¼	....	....	1	....	....	Do.
June 2	1 p. m	4 p. m	....	¼	....	....	1	....	....	Do.
June 7	1 p. m	——	....	¼	....	....	1	....	....	Do.
June 9	2 p. m	2:30 p. m.	....	1	....	1	....	....	....	Do.
June 20	3:10 p. m.	5 p. m	....	¼	....	....	1	....	....	Hy. rain, thunder.
June 21	11 a. m	3 p. m	....	....	1	....	1	....	....	Distant thunder.
June 22	3 p. m	D. n	....	....	1	....	....	1	....	Lt. rain, high potential.
July 5	12:30 p. m.	1 p. m	....	....	1	....	....	1	....	Lt. rain.
July 6	12:30 p. m.	4 p. m	....	2	....	....	1	....	....	Lt. rain, thunder.

TABLE N.—*The potential on days on which precipitation occurred at Columbus, Ohio, March* 1, 1886, *to July* 28, 1888—Continued.

Date	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.		
1887.										
July 8	11:10 a. m..	11:50 a. m..	----	----	1	1	----	----	----	Lt. rain.
July 18	3 p. m	3:10 p. m...	----	4	----	----	1	----	----	Lt. rain from clear sky.
July 21	10 a. m	10:20 a. m..	----	1	----	1	----	----	----	Lt. rain.
Aug. 11	Late p. m..	D. n.....	----	8	----	1	----	----	----	Do.
Aug. 17	10:45 a. m..	11 p. m	----	2	----	----	1	----	----	Do.
Aug. 22	All day		1	----	----	----	----	1	----	Do.
Sept. 6	9:30 a. m...	9:40 a. m...	----	½	----	----	1	----	----	Do.
Sept. 7	9 a. m	11 a. m	1	----	----	----	1	----	----	Lt. rain, thunder.
Sept. 22	Late p. m..	D. n.....	----	8	----	1	----	----	----	Lt. rain.
Sept. 27	All day		1	----	----	----	1	----	----	Do.
Sept. 28	All day		1	----	----	----	1	----	----	Do.
Sept. 30	7 p. m	9 p. m	----	4	----	1	----	----	----	Do.
Oct. 10	10 a. m	D. n.....	----	---	1	----	----	1	----	Do.
Oct. 11	1:30 p. m...	5 p. m	----	----	1	----	----	1	----	Do.
Nov. 14	D. n	10 a. m	1	----	----	----	----	1	----	Do.
Nov. 15	11 a. m	11:30 a. m..	----	----	1	----	----	1	----	Do.
Nov. 24	All day		1	----	----	----	----	1	----	Do.
Nov. 25	D. n	2 p. m	1	----	----	----	1	----	----	Do.
Dec. 20	3 p. m	6 p. m	----	----	1	----	----	1	----	Do.
Dec. 29	11 a. m	11:30 a. m..	----	----	1	----	----	1	----	Lt. snow.
1888.										
Jan. 5	11 a. m	3 p. m	----	2	----	----	1	----	----	Lt. rain.
Jan. 6	All day		1	----	----	----	----	1	----	Do.
Jan. 7	11 a. m	11:10 a. m..	----	----	1	----	----	1	----	Lt. snow.
Jan. 13	D. n	10 a. m	1	----	----	----	1	----	----	Lt. rain.
Jan. 17	D. n	12 m	1	----	----	----	1	----	----	Do.
Jan. 25	All day		1	----	----	----	1	----	----	Do.
Jan. 27	D. n	9:30 a. m...	1	----	----	----	----	1	----	Lt. snow.
Jan. 31	D. n	9:30 a. m...	1	----	----	----	----	1	----	Lt. rain.
Feb. 24	3 p. m	4 p. m	----	----	1	----	----	1	----	Lt. rain, mist.
Feb. 29	11 a. m	——.....	----	----	1	----	----	1	----	Lt. rain and sleet.
Mar. 2	D. n	10 a. m	1	----	----	----	----	1	1	Lt. rain.
Mar. 16	1:30 p. m...	2 p. m	----	----	1	1	----	----	----	Do.
Mar. 23	1 p. m	3 p. m	----	----	1	----	----	1	----	Lt. snow.
Mar. 24	9 a. m	11 a. m	----	----	1	----	----	1	----	Do.
Mar. 27	3 p. m	4 p. m	----	----	1	----	----	1	----	Hy. rain.
Apr. 10	D. n	10:30 a. m..	1	----	----	----	----	1	----	Lt. rain.
Apr. 19	9:40 a. m...	10:30 a. m..	----	----	1	----	----	1	1	Do.
Apr. 20	3 p. m	——.....	----	----	1	----	----	1	----	Lt. snow.
Apr. 30	1:20 p. m...	7 p. m	----	½	----	----	1	----	----	Lt. rain.
May 4	10:30 a. m..	12:15 p. m..	----	2	----	----	1	----	----	Hy. rain, thunder.
May 4	3 p. m	6 p. m	----	2	----	----	1	----	----	Lt. rain.
May 8	D. n	10 a. m	1	----	----	----	1	----	----	Hy. rain
May 18	D. n	10:30 a. m..	1	----	----	----	1	----	----	Do.
May 25	9 a. m	11 a. m	1	----	----	----	----	1	----	Lt. rain, mist.
June 14	3 p. m	——.....	----	½	----	----	1	----	----	Thunderstorm.
June 27	8 a. m	3 p. m	1	----	----	----	----	1	----	Lt. rain.
July 18	1 p. m	2 p. m	----	----	1	----	----	1	----	Do.
	Total (124).....		52	43	29	24	46	54	2	

SUMMARY.

	Before.			During.			Negative after.
	No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.	
Rain (103).....	38	42	23	23	43	37	2
Snow (20).....	13	1	6	1	2	17	0
Rain and snow (1).....	1	0	0	0	1	0	0
Total (124).....	52	43	29	24	46	54	2

TABLE O.—*Potentials on days on which precipitation occurred at Ithaca, N. Y., October*, 1887, *to August*, 1888.

[Extracts from daily journal.]

Date.	Remarks.
1887.	
Oct. 5	Lt. rain 7:30 a. m. to 2:40 p. m.; no special observations; negative at 1 p. m.
Oct. 7	Threatening weather 10:30 a. m. to 2:30 p. m.; lt. rain 12 m. to 12:10 p. m.; no special observations; positive at regular observations.
Oct. 20	Lt. rain 7:30 to 10 p. m.; negative potential at 9 and 11 a. m.
Oct. 21	Lt. rain 9:05 a. m. to 12:10 p. m; no special observations; negative at 9 a. m.
Oct. 22	Lt. snow 8:30 a. m. to 11:30 a. m.; no special observations; positive at 9 and 11 a. m.; lt. snow 1:45 to 2:15 p. m.; no special observations; negative at 1 p. m.
Oct. 30	Lt. snow 11:15 a. m. to 12:10 p. m.; no special observations; positive at all regular observations.
Nov. 4	Lt. rain 1:25 to 1:50 p. m.; weather threatening 10 a. m. to 1:25 p. m.; positive 9 to 10:50 a. m.; positive and negative 10:50 a. m. to 1:20 p. m.; positive 1:20 to 5 p. m.
Nov. 10	Lt. rain 6:45 to 9:27 a. m.; high positive and negative 9 to 9:27 a. m.; high positive, with sparks, 9:30 to 10:50 a. m.; lt. rain 11:01 to 11:04 a. m.; negative 10:50 to 11:10 a. m.; positive and negative 11:15 to 11:35 a. m.; lt. rain 3:20 to 6:40 p. m.; variable positive and negative 3:20 to 4 p. m.; potential zero 1:30 to 3:25 p. m.
Nov. 11	Lt. and heavy snow 9 p. m. on 10th to 10:04 a. m. to-day; lt. and heavy snow 10:16 a. m. to 12:40 p. m.; lt. and heavy snow 1.30 p. m. to during night; high positive all day; often the potential was so high that discharges took place between the needle and quadrants; during intervals of no precipitation there was a fall in potential.
Nov. 14	Lt. rain 7:30 p. m. to 3 a. m on 15th; no negative observed up to 5 p. m., though there was a steady fall of potential from 10 a. m.
Nov. 15	Sprinkling rain 2:15 to 7 p. m.; weather was threatening from 9 a. m. to 2:15 p. m.; positive all day, potential low, and variations were slow and small.
Nov. 18	Lt. snow began and ended during early morning; potential was positive during the evening of the 17th, but there was a fall from 3 to 5 p. m.
Nov. 19	Lt. snow 9:20 to 9:28 a. m.; 9:43 to 9:54 a. m.; negative 8:55 to 9:20 a. m.; positive and negative 9:20 to 9:54 a. m.; sleet 11:45 a. m. to 2:30 p. m.; hy. snow 2:30 to 4:40 p. m.; sleet 4:40 to 5:56 p. m.; positive and negative 10 a. m. to 2 p. m.; positive 2 to 6:30 p. m.
Nov. 24	Lt. rain 11:40 to 11:54 a. m.; sleet 11:54 a. m. to 12:40 p. m.; lt. snow 12:40 to 1:40 p. m.; lt. rain 1:40 p. m. and during night; dense fog from 9 to 11:40 a. m.; positive and negative 9:40 to 11:47 a. m.; positive during remainder of the day.
Nov. 25	Hy. rain 10 p. m. and during night; negative 10:41 to 11:05 a. m.; weather threatening all day and wind southerly.
Nov. 28	Sleet early a. m. to 10:10 a. m.; negative was observed during the morning and early evening of the 27th and all of this day except from 10:39 to 10:52 a. m., when the potential was positive.
Nov. 30	Heavy snow 8:30 to 11:58 a. m.; positive all day.
Dec. 2	Rain 6:40 p. m. and during night; cloudy, threatening weather all day; negative at 9 to 11 a. m.
Dec. 4	Rain 6 p. m. and during night; positive and negative 9 a. m. to 5 p. m.
Dec. 5	Lt. snow 1:10 to 3:30 p. m.; cloudy all day; positive and negative all day; chiefly negative during time of no precipitation; chiefly positive during precipitation.
Dec. 8	Mist 11:10 to 11:20 a. m.; cloudy, threatening weather all day: positive and negative 10:51 to 10:57 a. m.; positive during rest of the day except from 2:13 to 2:24 p. m., when it was negative.
Dec. 10	Lt. rain all day until 4:45 p. m.; positive 8 to 8:23 a. m.; negative 8:24 to 10:20 a. m.; positive 10:20 a. m. to 5 p. m.
Dec. 12	Lt. snow 12:28 to 3:15 p. m.; snow was very light and fine (trace); negative 8:30 to 9:30 a. m.; positive and negative 9:30 a. m. to 1 p. m.; positive 1 to 5 p. m.
Dec. 15	Sleet 1:10 to 2:35 p. m.; weather cloudy and threatening all day; positive all day.
Dec. 17	Snow 5:05 p. m., continued during night; positive all day; weather cloudy.
Dec. 18	Lt. snow all day; high positive all day.
Dec. 20	Sleet 4:15 p. m. and during night; weather threatening during evening from 1 p. m.; high positive all day.
Dec. 22	Heavy snow 9:30 to 11:45 a. m.; positive 9 a. m. to 12 m.; variable positive and negative from 1 to 5 p. m.
Dec. 23	Lt. snow 8:30 a. m. to 1:31 p. m.; positive all day.
Dec. 25	Lt. snow 12:40 to 2 p. m.; weather cloudy; positive all day.
Dec. 26	Lt. snow 7:15 to 10 a. m.; 1:45 p. m. and during night; positive all day.
Dec. 28	Sleet early a. m. to 12:45 p. m.; snow 12:45 to 1:50 p. m.; negative 7 to 9 p. m. on 27th; positive 8 to 9:25 a. m.; positive and negative 9:25 a. m. to 1 p. m.; positive 1 to 1:50 p. m.
Dec. 29	Lt. snow all day (trace); high positive all day; sparks passed immediately upon connecting up the electrometer and water dropper.
Dec. 30	Lt. snow early a. m. to 9:45 a. m.; 11:40 a. m. to 1:50 p. m.; 3:55 to 4:25 p. m.; positive all day.
Dec. 31	Lt. snow 9:50 a. m. to 1:05 p. m.; 2 to 5:40 p. m.; negative 1:05 to 1:40 p. m.
1888.	
Jan. 1	Lt. rain early a. m. to 9:40 a. m.; 6:45 to 9:10 p. m.; high negative at 9 a. m.; negative variable at 1 to 3 and 5 p. m.; sparks were obtained at 9 a. m.; no observations after 5 p. m.

TABLE O.—*Potential on days on which precipitation occurred at Ithaca, N. Y., October*, 1887, *to August*, 1888—Continued.

Date.	Remarks.
1888.	
Jan. 2	Lt. snow 9:20 to 10:55 a. m.; 12:30 to 1:35 p. m.; 2:50 to 3:15 p. m.; negative 9:04 to 9:15 a. m.; positive at all other times until 5 p. m.; during the light flurries of snow in the afternoon the potential rose between 100 and 200 volts, but did not change to negative; (trace).
Jan. 3	Lt. snow early a. m. to 3:20 p. m.; negative 9 a. m. to 3 p. m.; variable positive and negative 3 to 5 p. m.; negative 5 to 6:20 p. m.; precipitation from 11 a. m. to 3:20 p. m. was very light and snow was very moist.
Jan. 4	Lt. snow 7:45 to 10:10 a. m.; 3:04 p. m. and during night; positive 9 a. m. to 3:20 p. m.; negative 3:21 to 3:55 p. m.; positive 3:55 to 5 p. m.
Jan. 5	Lt. snow continued until 9:35 a. m.; positive 9 to 9:35 a. m.; precipitation was very light.
Jan. 6	Sleet early a. m. to 2:20 p. m.; 4 to 4:45 p. m.; negative was observed during the evening of the 5th; negative 9 a. m. to 2:40 p. m.; positive 2:40 to 5 p. m. The magnitude of the negative potential increased gradually from 9 a. m.: 9 a. m. —50 volts; 9:30 a. m. —1,300 volts; 10 a. m. —off scale; 10:30 a. m. —sparks; sparks continued to pass rapidly, after exposure of the collector, until 2:05 p. m.; at 2:10 p. m. readings could again be taken and the potential was —5,000 volts; it fell slowly to zero at 2:40 p. m., became +100 volts at 2:45 p. m., and continued steady; sleet ended at 2:20 p. m.; precipitation from 4 to 4:45 p. m.; did not seem to affect the potential.
Jan. 8	Lt. snow early a. m. to 10 a. m.; variable positive and negative 7:30 to 9:31 p. m. on 7th, and 8:30 to 11:46 a. m. to-day; negative 11:47 a. m. to 10 p. m., except variable positive 3 to 3:15 p. m.
Jan. 9	Lt. snow early a. m. to 6 p. m.; potential variable positive and negative during morning; negative during evening; precipitation very light (trace 1 to 5 p. m.).
Jan. 10	Lt. snow early a. m. to 10:40 a. m.; 12:55 to 2 p. m.; positive 9 to 10:50 a. m.; negative 11 a. m. to 12:50 p. m.; positive 12:55 to 5 p. m.; snow ended 10:40 a. m.; potential changed from positive to negative at 10:55 a. m. and remained negative until 12:55 p. m., when snow began again. Although snow continued to fall about 8 miles southwest of the station from 10:40 a. m. to 12 m., the potential at Ithaca did not seem to be affected by it.
Jan. 11	Lt. snow 10 a. m. to 12:10 p. m.; positive all day; potential was steady before snow fell, but rose rapidly from +950 volts at 9:55 a. m. to +3,450 volts at 10 a. m., when snow began. After snow ended it fell rapidly to about +750 volts and remained steady, decreasing slowly during the remainder of the day.
Jan. 12	Lt. snow early a. m. to 9:45 a. m.; positive all day.
Jan. 13	Sleet 10:50 to 11:13 a. m.; lt. rain 11:13 a. m. to 12:10 p. m.; positive 9 to 11:10 a. m.; negative 11:13 a. m. to 12:20 p. m.; positive after.
Jan. 14	Lt. snow early a. m. to 9:30 a. m.; positive all day.
Jan. 15	Lt. rain early a. m. to 10:15 a. m.; 12:15 to 2:30 p. m.; lt. snow 2:30 to 4:20 p. m.; variable positive and negative all day; positive during snow.
Jan. 16	Lt. snow early a. m. to 10 a. m.; positive all morning; negative during afternoon and night.
Jan. 17	Heavy snow 10:40 a. m. to 4:21 p. m.; lt. rain 4:21 to 5:30 p. m.; snow 5:30 p. m. and during night; negative 9:17 to 10:05 a. m.; positive 10:05 a. m. to 4:20 p. m.; negative 4:22 to 5 p. m.; no observation after 5 p. m. Potential changed from positive to negative as precipitation changed from snow to rain.
Jan. 18	Lt. snow continued from 17th to 12 m. to-day; 4:15 to 8 p. m.; potential positive all day, and increased whenever precipitation became heavier; snow fell all day in sight of the station, but did not seem to affect the potential, except when falling at the station.
Jan. 19	Lt. snow 10:30 a. m. to 2:35 p. m. (trace); positive all day; varied in magnitude during snowfall; at 9 a. m. snow was falling at several points along the horizon, especially in the NW., yet the potential remained steady at Ithaca.
Jan. 21	Lt. snow early a. m. to 11:50 a. m. (trace); positive all day; potential very high and fluctuated during snow.
Jan. 22	Lt. snow 8 a. m. to 1:15 p. m. (trace); potential positive all day; precipitation very light indeed and fluctuations in potential were not great.
Jan. 24	Lt. snow 5:40 p. m. on 23d to 10:45 a. m. to-day; 12:30 to 12:50 p. m.; 2:40 to 4 p. m. (trace from 9 a. m. to 3 p. m.; 0.01 of an inch 3 to 4 p. m.); positive all day; fluctuated greatly during snow; greatest amount of precipitation and highest potentials occurred between 3 and 4 p. m.
Jan. 25	Lt. snow 3:40 p. m. and during night; positive all day.
Jan. 26	Lt. snow 8:45 a. m. to 5:45 p. m. (0.01 inch from 9 to 11 a. m., trace 11 a. m. to 5 p. m.); potential positive all day, and so high that it was impossible to take any readings on account of sparks, which passed even when the battery was disconnected from the quadrants.
Feb. 1	Lt. snow 10:30 a. m. to 2:05 p. m.; 4:30 to 5:20 p. m.; potential positive all day; fluctuations were not great.
Feb. 4	Sleet early a. m. to 1:50 p. m.; lt. rain 2:30 to 5:30 p. m.; potential negative all day; sparks passed between needle and quadrants at 9:35 and 11:20 a. m., the times of heaviest precipitation.
Feb. 7	Lt. snow 2:35 to 3:45 p. m.; potential positive all day; it fluctuated greatly during snowfall, and sparks were obtained from 3:15 to 3:45 p. m., though there was no perceptible variation in the amount of precipitation.
Feb. 8	Lt. snow 7:30 to 9:45 a. m., heavy 9:45 a. m. to 2:40 p. m.; lt. snow 2:40 to 3:30 p. m.; potential rose gradually from +800 volts at 9 a. m. to +2,150 volts at 9:30 p. m.; at 9:55 a. m. there was a sudden rise in potential to more than +5,000 volts; sparks began to pass and continued until 2:40 p. m., when precipitation decreased in amount; after snow ceased falling the potential remained nearly steady.

TABLE O.—*Potential on days on which precipitation occurred at Ithaca, N. Y., October*, 1887, *to August*, 1888—Continued.

Date.	Remarks
1888.	
Feb. 10	Lt. snow 3:45 to 7 p. m. (trace); potential varied from positive to negative between 12 m. and 3:45 p. m.; high positive 3:49 to 7 p. m.; precipitation very light.
Feb. 11	Lt. snow 9:20 to 10:10 a. m. (trace); positive all day; potential fell slowly during snowfall.
Feb. 15	Lt. snow early a. m. to 6:30 p. m.; potential positive all day, and so high that sparks passed and it was impossible to take readings of the electrometer; the snow drifted heavily as it fell.
Feb. 17	Lt. snow 10:55 p. m to 12 midnight; potential positive all day; rose slightly during precipitation, which was very light indeed.
Feb. 18	Lt. snow 12:01 a. m. to 10:40 a. m.; potential positive all day except 7:40 to 7:50 a. m., when it was negative.
Feb. 20	Lt. rain 7 to 7:20 p. m.; potential variable from positive to negative 9 to 9:30 a. m. and 6:40 to 7:39 p. m.
Feb. 22	Lt. snow 8:55 to 11:15 a. m.; negative all day except at 9:30 for 20 sec. a. m., when it was positive; negative all day on 21st until 11 p. m.
Feb. 25	Sleet early a. m. to 9:30 a. m.; lt. rain 9:30 to 11:54 a. m., 1:50 to 2:32 p. m.; potential negative 8:30 to 11:54 a. m.; positive 11:54 a m. to 2:32 p. m.
Feb. 26	Heavy snow 11:40 a. m. to 12:25 p. m.; negative 10 to 10:10 a. m., 12:44 and 12:50 p. m.; sparks were obtained during snow.
Feb. 27	Lt. snow 1:03 to 1:15 p. m., 2:55 to 3:20 p. m., 3:40 to 4 p. m.; potential negative 9 to 10 a. m.; variable from positive to negative 10 to 11 a. m.; negative 11 a. m. to 12:40 p. m.; positive 12:40 to 12:55 p. m.; negative all other times during the day except at 3:45 p. m., when it was positive.
Mar. 1	Lt. snow 2:55 p. m. and during night; negative 11:44 a. m. to 2:54 p. m.; variable from positive to negative 2:55 to 6 p. m.
Mar. 2	Sleet early a. m. to 10:30 a. m.; lt. rain 12:45 p. m. and during night; potential negative 8:45 to 10:44 a. m. except at 9:09, when it was positive; positive 10:44 a. m. to 2 p. m.; variable from positive to negative 2 to 5 p. m.
Mar. 3	Lt. and heavy snow all day; potential high positive all day and fluctuated with the amount of precipitation.
Mar. 6	Lt. snow 11:25 to 11:40 a. m. (trace); potential positive and pretty steady; precipitation very light.
Mar. 7	Lt. snow 5 p. m. and during night; positive all day; no observations after 5 p. m.
Mar. 8	Lt. snow 11 to 11:30 a. m., 2:30 to 4:45 p. m.; potential positive all day and fluctuated during snow.
Mar. 11	Lt. rain 12:35 to 4:20 p. m.; heavy rain 4:20 to 4:58 p. m.; heavy snow 4:58 p. m. to during night; potential positive 9 a. m. to 2:15 p. m.; variable from positive to negative 2:15 to 3:10 p. m.; positive 3:10 to 7 p. m. At 4:20 p. m. when the rain became heavy there was a sudden increase in potential of more than 1,000 volts; it continued increasing; at 4:42 p. m. it was +5,000 volts as rain turned to snow; at 4:58 p. m. it was about +6,000 volts and at 5:10 p. m. it was impossible to take readings owing to sparks passing between needle and electrometer; after 5:20 p. m. it was possible to get sparks ½ an inch long from a cascade of Leyden jars connected up with the water dropper; the jars discharged with a very loud report; a blizzard struck the station at 5.19 p. m.
Mar. 12	Lt. snow continued until 9:30 a. m.; 12:10 p. m. and during night; potential high positive all day; impossible to take readings of the electrometer on account of sparks.
Mar. 13	Lt. snow all day; potential very high negative; impossible to take readings of the electrometer; sparks an inch long were obtained from a cascade of Leyden jars connected with the collector.
Mar. 14	Lt. snow 2:55 to 3.40 p. m.; potential positive all day, and was less during precipitation than when there was none.
Mar. 16	Lt. rain 12:15 to 12:40 p. m.; lt. snow 4:50 to 7 p. m.; potential variable from positive to negative 8:30 a. m. to 1:22 p. m.; positive 1:22 to 5 p. m.; variable from positive to negative 5 to 5:35 p. m.; no observations after 5:35 p. m.
Mar. 17	Lt. snow early a. m. to 11:20 a. m.; potential positive all day; very high during snow.
Mar. 22	Lt. snow 12:15 to 2:40 p. m.; negative at 9 and 11 a. m.; high positive during snow; variable from positive to negative after 2:40 p. m.
Mar. 26	Lt. rain early a. m. to 2 p. m.; potential variable from positive to negative 9 a. m. to 2:30 p. m.; very high negative at 11 a. m. and 1 p. m.; no special observation.
Mar. 28	Rain 5:07 p. m. and during night; negative at 5 p. m.
Mar. 30	Lt. rain 12:58 to 1:15 p. m.; lt. snow 4 to 4:30 p. m.; negative at 9 to 11 a. m. and 1 and 3 p. m.; no special observation.
Apr. 1	Heavy rain 4 to 6:30 p. m.; potential variable from positive to negative all day.
Apr. 2	Lt. rain 4:45 to 5:10 p. m.; potential negative all day; no special observation.
Apr. 3	Lt. snow 10:35 to 10:55 a. m.; potential negative all day.
Apr. 5	Lt. rain 9:15 to 11:20 a. m.; lt. rain 5:10 to 6 p. m.; potential positive 9 a. m. to 1 p. m.; very high from 11 a. m. to 1 p. m.; variable from positive to negative 1 to 4 p. m.
Apr. 10	Lt. rain 8 a. m. to 4:20 p. m.; positive 9 to 9:20 a. m.; negative 9:20 a. m. to 4 p. m.; positive 4 to 5 p. m.
Apr. 12	Lt. snow 2:25 to 3:20 p. m. (trace); potential variable from positive to negative 8:45 a. m. to 3 p. m.; negative 3 to 11 p. m.

TABLE O.—*Potential on days on which precipitation occurred at Ithaca, N. Y., October, 1887, to August, 1888*—Continued.

Date.	Remarks.
1888.	
Apr. 14	Lt. rain early a. m. to 10:15 a. m.; 11:02 to 11:22 a. m.; 12:30 to 6 p. m.; precipitation from 3:40 to 6 p. m. was a mixture of rain and snow; potential negative all day.
Apr. 18	Lt. rain early a. m. to 9 a. m.; potential negative all day on the 17th; potential variable from positive to negative 7:30 to 10 a. m. to-day; very high during precipitation, sparks were obtained 7:45 to 8:35 a. m.
Apr. 19	Lt. rain 5:45 to 5:50 p. m. (trace); potential positive 9 to 10:15 a. m.; negative 10:15 a. m. to 6 p. m.
Apr. 20	Lt. snow early a. m. to 10:45 a. m.; 4:40 to 8 p. m.; potential negative 9 to 10:45 a. m.; variable from positive to negative 10:45 to 11:30 a. m.; negative 11:30 a. m. to 5 p. m.; no observation after 5 p. m.
Apr. 21	Lt. snow 11:02 a. m. to 12 m. (trace); potential negative 9 to 9:40 a. m.; variable positive to negative 9:40 a. m. to 12:40 p. m.; negative 12:40 to 5 p. m.
Apr. 24	Light flurries of snow at 9:20 and 9:45 a. m.; potential negative 9 to 10:55 a. m.
May 1	Rain during early a. m. (trace); potential negative; dense haze during evening of April 30.
May 2	Lt. rain during early a. m. (trace); potential negative during evening of May 1.
May 4	Lt. rain 6:30 to 8:30 a. m.; potential fell during evening of May 3, but did not change to negative during the time that observations were taken.
May 8	Lt. rain 8 a. m. to 12:30 p. m.; potential variable from positive to negative 9 a. m. to 12 m.; positive during remainder of the day.
May 10	Lt. rain 1:55 to 2:15 p. m.; heavy rain 3:52 to 4:20 p. m.; thunderstorm; potential positive 9 a. m. to 3 p. m.; variable positive to negative 3 to 4:50 p. m.
May 12	Lt. rain 11:15 a. m. to 12:40 p. m.; thunderstorm; lt. rain 4:10 to 4:40 p. m.; thunderstorm; potential variable positive to negative all day.
May 13	Rain 6:35 to 7:30 p. m.; potential negative all day.
May 14	Lt. rain 8:30 a. m. to 12:30 p. m.; potential variable positive to negative 9 a. m. to 12:10 p. m.; negative 12:10 to 6 p. m.
May 15	Lt. rain 11:30 a. m. to 12:15 p. m.; heavy rain and hail 1:15 to 1:55 p. m.; potential negative all day except at 1:30, 2:30, 4:20, and 4:40 p. m., when it was positive; potential during rain and hail, 1:15 to 1:55 p. m., was variable and so high that sparks were obtained.
May 16	Lt. rain 8:55 to 10 a. m.; 11:40 a. m. to 12:05 p. m.; 12:25 to 1:15 p. m.; 1:50 to 2:50 p. m.; potential positive 9 to 11:10 a. m.; variable from positive to negative 11:10 a. m. to 4:10 p. m.; during the interval of no rain, 12:05 to 12:25 p. m., the potential was highest and variable from positive to negative; sparks passed almost continually; the clouds hung so low during that time that only the base of hills 2 miles away across the valley could be seen; the hill tops were hidden.
May 18	Lt. rain 10:30 to 10:50 a. m.; 12:45 to 4:15 p. m.; potential variable positive to negative 9 a. m. to 3:30 p. m.; positive 3:30 to 5 p. m.
May 25	Lt. rain 4:35 p. m. and during night; potential positive all day; no special observations.
May 27	Lt. rain 7:45 to 8:15 p. m.; potential variable from positive to negative all day; no observations after 5 p. m.
May 28	Lt. rain 8:30 to 9:25 a. m. (trace); potential variable positive to negative 8:50 to 10 a. m.; positive after; precipitation was very light but the potential was so high at times that sparks passed between needle and quadrants.
May 29	Lt. rain 9:50 to 10:30 a. m.; potential negative 9 to 9:30 a. m.; variable from positive to negative 9:30 to 11:40 a. m.; positive during rest of the day.
May 31	Lt. rain 3:31 to 4:07 p. m.; thunderstorm; potential variable positive to negative 9:40 to 11:40 a. m.; positive 11:40 a. m. to 3:10 p. m.; variable from positive to negative (chiefly negative) 3:10 to 4:35 p. m.; positive after that time.
June 2	Heavy rain 2:25 to 3:30 p. m.; thunderstorm; potential variable positive to negative all day, and so high during rain that it was impossible to take readings on account of sparks.
June 10	Lt. rain 9:45 to 11:30 p. m.; thunderstorm; no observations; there was a fall of potential from 3 to 5 p. m.
June 11	Lt. rain 2 to 3:15 p. m. (trace); potential variable from positive to negative all day.
June 15	Lt. rain 7 to 9:30 a. m.; observations from 9 to 9:30 a. m. only; potential positive all day.
June 23	Lt. and heavy rain 12:30 to 2:45 p. m.; thunderstorm; potential positive 9 a. m. to 12 m.; variable from positive to negative 12 m. to 2:45 p. m.; positive after that time.
June 24	Lt. rain 2:50 to 4:10 p. m.; thunderstorm; potential positive during morning; variable from positive to negative during the remainder of the day.
June 26	Lt. rain 8 to 9:10 a. m.; observations began at 9 a. m.; potential positive all day.
June 28	Lt. rain all day; potential positive all day.
June 29	Lt. rain continued until 10:10 a. m.; potential positive all day.
July 5	Lt. rain 12:15 to 12:55 p. m.; thunderstorm; potential variable from positive to negative 10 a. m. to 2:30 p. m.; positive at other times during the day.
July 8	Lt. rain 10 p. m. and during night; potential variable from positive to negative 12 m. to 5 p. m.; no observations after 5 p. m.
July 18	Lt. rain 2:30 to 5:30 p. m.; potential variable from positive to negative during the whole day.
July 19	Heavy rain 2:35 to 2:55 p. m.; lt. rain 3:15 to 3:40 p. m.; potential variable from positive to negative all day.
July 26	Lt. rain 1:05 to 3:28 p. m.; 5:05 p. m. and during night; potential variable from positive to negative 12 m. to 5 p. m.

TABLE O.—*Potential on days on which precipitation occurred at Ithaca, N. Y., October*, 1887, *to August*, 1888—Continued.

Date.	Remarks.
1888.	
July 31	Lt. rain 2:10 to 2:55 p. m.; potential variable from positive to negative 12:30 to 4:30 p. m.
Aug. 4	Rain 5:30 to 7:15 p. m.; thunderstorm; potential negative at 5 p. m.
Aug. 8	Lt. rain 5:20 to 5:25 p. m.; fine shower rain from a single isolated cloud; potential positive all day.
Aug. 11	Lt. rain 12 m. to 12:55 p. m, 0.01 inch; potential positive all day; low during precipitation.
Aug. 12	Lt. rain 3 to 10 a. m.; potential negative at 9 a. m.; positive during rest of day.
Aug. 13	Lt. rain 8:35 to 10 a. m.; potential negative at 9 a. m.; positive during rest of day.
Aug. 17	Lt. rain 8 to 10:45 a. m.; potential steady positive all day.
Aug. 21	Lt. rain 2:20 p. m. and during night; potential steady positive all day.
Aug. 22	Lt. rain continued until 10:20 a. m.; potential low positive at 9 a. m.; increased slowly during the day.
Aug. 23	Lt. rain 4 to 4:15 p. m.; potential negative at 1 p. m.
Aug. 31	Lt. rain 7 to 11 p. m.; potential negative 3 and 5 p. m.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative observed.	No observation.	Negative.	No negative observed.		
1887.										
Oct. 5	7:30 a. m...	2:40 p. m...	1	....	....	....	1	....	....	Lt. rain.
Oct. 7	12 m	12:10 p. m..	....	....	1	1	....	....	....	Lt. rain; no sp'l obs.
Oct. 20	7:30 p. m...	10 p. m....	....	10	....	1	....	....	....	Lt. rain.
Oct. 21	9:05 a. m...	12:10 p. m..	....	½	....	....	....	1	....	Lt. rain; no sp'l obs.
Oct. 22	8:30 a. m...	11:30 a. m..	1	....	....	....	....	1	....	Lt. snow.
Oct. 22	1:45 p. m...	2:15 p. m...	....	¾	....	1	....	....	....	Lt. snow; no sp'l obs.
Oct. 30	11:15 a. m..	12:10 p. m..	....	....	1	1	....	....	....	Do.
Nov. 4	1:25 p. m...	1:50 p. m...	....	2½	....	....	....	1	....	Lt. rain.
Nov. 10	6:45 a. m ..	9:27 a. m...	1	....	....	....	1	....	....	Do.
Nov. 10	11:01 a. m..	11:04 a. m..	....	¼	....	....	1	....	....	Do.
Nov. 10	3:20 p. m...	6:40 p. m...	....	4	....	....	1	....	....	Do.
Nov. 11	All day.		1	....	....	....	....	1	....	Hy. snow.
Nov. 15	2:15 p. m...	7:10 p. m...	....	....	1	....	....	1	....	Mist, lt. rain.
Nov. 19	9:20 a. m...	9:54 a. m...	....	½	....	....	1	....	....	Lt. snow.
Nov. 19	11:45 a. m..	5:56 p. m...	....	1¾	....	....	1	....	....	Lt. snow and sleet.
Nov. 24	11:40 a. m..	D. n.....	....	2	....	....	1	....	....	Lt. snow, sleet and lt. rain.
Nov. 25	10 p. m	D. n.....	....	9	....	1	....	....	....	Lt. rain.
Nov. 28	Early a. m.	10:10 a. m..	1	....	....	....	1	....	....	Sleet.
Nov. 30	8:30 a. m...	12 m	1	....	....	....	....	1	....	Hy. snow.
Dec. 2	6:40 p. m...	D. n.....	....	9	....	1	....	....	....	Lt. rain.
Dec. 4	6 p. m	D. n.....	....	9	....	1	....	....	....	Do.
Dec. 5	1:10 p. m...	3:30 p. m...	....	4	....	....	1	....	....	Lt. snow.
Dec. 8	11:10 a. m..	11:20 a. m..	....	¼	....	....	....	1	....	Mist, lt. rain.
Dec. 10	Early a. m.	4:45 p. m...	1	....	....	....	1	....	....	Lt. rain.
Dec. 12	12:28 p. m..	3:15 p. m...	....	4	....	....	1	....	....	Lt. snow.
Dec. 15	1:10 p. m...	2:30 p. m...	....	....	1	....	....	1	....	Sleet.
Dec. 17	5:05 p. m...	D. n.....	....	....	1	1	....	....	....	Lt. snow.
Dec. 18	All day.		1	....	....	....	....	1	....	Do.
Dec. 20	4:15 p. m...	D. n.....	....	....	1	....	....	1	....	Sleet.
Dec. 22	9:30 a. m...	11:45 a. m..	....	½	....	....	1	....	1	Heavy snow.
Dec. 23	8:30 a. m...	1:31 p. m...	1	....	....	....	....	1	....	Lt. snow.
Dec. 25	12:40 p. m..	2 p. m	....	....	1	....	....	1	....	Do.
Dec. 26	7:15 a. m...	10 a. m	1	....	....	....	....	1	....	Do.
Dec. 26	1:45 p. m...	D. n.	....	....	1	....	....	1	....	Do.
Dec. 28	Early a. m.	1:50 p. m...	....	6	....	....	1	....	....	Lt. snow and sleet.
Dec. 29	All day.		1	....	....	....	....	1	....	Lt. snow, tr.; sparks.
Dec. 30	Early a. m.	4:25 p. m...	1	....	....	....	....	1	....	Lt. snow.
Dec. 31	9:50 a. m...	5:40 p. m...	....	....	1	....	1	....	....	Do.
1888.										
Jan. 1	Early a. m.	9:40 a. m...	1	....	....	....	1	....	....	Lt. rain.
Jan. 1	6:45 p. m...	9:10 p. m...	....	7	....	1	....	....	....	Lt. rain; sparks.
Jan. 2	9:20 a. m...	3:15 p. m...	....	¼	....	....	....	1	....	Lt. snow, tr.
Jan. 3	Early a. m.	3:20 p. m...	1	....	....	....	1	....	1	Lt. snow; moist.
Jan. 4	7:45 a. m...	10:10 a. m..	1	....	....	....	....	1	....	Lt. snow.

TABLE O.—*Potential on days on which precipitation occurred at Ithaca, N. Y., October, 1887, to August, 1888*—Continued.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative observed.	No observation.	Negative.	No negative observed.		
1888.										
Jan. 4	3:04 p. m...	D. n.....	----	----	1	----	1	----	----	Lt. snow.
Jan. 6	Early a. m.	4:45 p. m...	1	----	----	----	1	----	----	Sleet; sparks.
Jan. 8	Early a. m.	10 a. m....	----	7	----	----	1	----	1	Lt. snow.
Jan. 9	Early a. m.	6 p. m	1	----	----	----	1	----	----	Lt. snow, tr.
Jan. 10	Early a. m.	10:40 a. m..	1	----	----	----	----	1	----	Lt. snow.
Jan. 10	12:55 p. m..	2 p. m	----	2	----	----	----	1	----	Do.
Jan. 11	10 a. m	12:10 p. m..	----	----	1	----	----	1	----	Lt. snow; sparks.
Jan. 13	10:50 a. m..	12:10 p. m..	----	----	1	----	1	----	----	Sleet and rain.
Jan. 14	Early a. m.	9:30 a. m...	1	----	----	----	----	1	----	Lt. snow.
Jan. 15	Early a. m.	4:20 p. m...	1	----	----	----	1	----	----	Lt. snow and lt. rain.
Jan. 16	Early a. m.	10 a. m	1	----	----	----	----	1	1	Lt. snow.
Jan. 17	10:40 a. m..	D. n.....	----	1	----	----	1	----	----	Heavy snow and rain.
Jan. 18	4:15 p. m...	8 p. m	----	----	1	----	----	1	----	Lt. snow.
Jan. 19	11:30 a. m..	2:35 p. m...	----	----	1	----	----	1	----	Lt. snow, tr.
Jan. 21	Early a. m.	11:50 a. m..	1	----	----	----	----	1	----	Lt. snow, tr.; sparks.
Jan. 22	8 a. m	1:15 p. m...	1	----	----	----	----	1	----	Lt. snow, tr.
Jan. 24	Early a. m.	4 p. m	1	----	----	----	----	1	----	Lt. snow; sparks.
Jan. 25	3:40 p. m...	D. n.....	----	----	1	----	----	1	----	Lt. snow.
Jan. 26	8:45 a. m...	5:45 p. m...	1	----	----	----	----	1	----	Lt. snow; sparks.
Feb. 1	11:30 a. m..	5:20 p. m...	----	----	1	----	----	1	----	Lt. snow.
Feb. 4	Early a. m.	5:30 p. m...	1	----	----	----	1	----	----	Sleet and rain.
Feb. 7	2:35 p. m...	3:45 p. m...	----	----	1	----	----	1	----	Lt. snow; sparks.
Feb. 8	7:30 a. m...	3:30 p. m...	1	----	----	----	----	1	----	Lt. and heavy snow; sparks.
Feb. 10	3:45 p. m...	7 p. m	----	$3\frac{3}{4}$	----	----	1	----	----	Lt. snow, tr.; + sparks.
Feb. 11	9:20 a. m...	10:10 a. m..	----	----	1	----	----	1	----	Lt. snow, tr.
Feb. 15	Early a. m	6:30 p. m...	1	----	----	----	----	1	----	Lt. snow; sparks.
Feb. 18	12:01 a. m..	10:40 a. m..	----	----	1	----	1	----	----	Lt. snow.
Feb. 20	7 p. m	7:20 p. m...	----	$\frac{1}{4}$	----	----	1	----	1	Lt. rain.
Feb. 22	8:55 a. m...	11:15 a. m..	----	$3\frac{1}{2}$	----	----	1	----	----	Lt. snow.
Feb. 25	Early a. m.	2:30 p. m...	1	----	----	----	1	----	----	Sleet and rain.
Feb. 26	11:40 a. m..	12:25 p. m..	----	2	----	----	----	1	1	Heavy snow; sparks.
Feb. 27	1:03 p. m...	4 p. m	----	8	----	----	1	----	----	Lt. snow.
Mar. 1	2:55 p. m...	D. n.....	----	3	----	----	1	----	----	Do.
Mar. 2	Early a. m.	D. n.....	1	----	----	----	1	----	----	Sleet and rain.
Mar. 3	All day.		1	----	----	----	----	1	----	Lt. and heavy snow; sparks.
Mar. 6	11:25 a. m..	11:40 a. m..	----	----	1	----	----	1	----	Lt. snow, tr.
Mar. 7	5 p. m	D. n.....	----	----	1	1	----	----	----	Lt. snow.
Mar. 8	11 a. m	4:45 p. m...	----	----	1	----	----	1	----	Do.
Mar. 11	12:35 p. m..	D. n.....	----	----	1	----	1	----	----	Rain and heavy snow; sparks.
Mar. 12	12:10 p. m..	D. n.....	----	----	1	----	----	1	----	Lt. snow; sparks.
Mar. 13	All day.		1	----	----	----	1	----	----	Lt. snow; — sparks.
Mar. 14	2:50 p. m...	3:40 p. m...	----	----	1	----	----	1	----	Lt. snow.
Mar. 16	12:15 p. m..	12:40 p. m..	----	4	----	----	1	----	----	Lt. rain.
Mar. 16	4:50 p. m...	7 p. m	----	5	----	----	1	----	----	Lt. snow.
Mar. 17	Early a. m.	11:20 a. m..	1	----	----	----	----	1	----	Lt. snow; sparks.
Mar. 22	12:15 p. m..	2:40 p. m...	----	3	----	----	----	1	1	Do.
Mar. 26	Early a. m.	2 p. m	1	----	----	----	1	----	1	Lt. rain.
Mar. 28	5:07 p. m...	D. n.....	----	$1\frac{1}{2}$	----	1	----	----	----	Do.
Mar. 30	12:58 p. m..	1:15 p. m...	----	4	----	----	1	----	----	Do.
Mar. 30	4 p. m	4:30 p. m...	----	3	----	1	----	----	----	Lt. snow.
Apr. 1	4 p. m	6:30 p. m...	----	7	----	----	1	----	----	Heavy rain.
Apr. 2	4:45 p. m...	5:10 p. m...	----	8	----	----	1	----	----	Lt. rain.
Apr. 3	10:35 a. m..	10:55 a. m..	----	3	----	----	1	----	1	Lt. snow.
Apr. 5	9:15 a. m...	11:20 a. m..	----	$\frac{1}{4}$	----	----	1	----	----	Lt. rain.
Apr. 5	5:10 p. m...	6 p. m	----	5	----	----	1	----	----	Do.
Apr. 10	8 a. m	4:20 p. m...	1	----	----	----	1	----	----	Do.
Apr. 12	2:25 p. m...	3:20 p. m...	----	6	----	----	1	----	1	Lt. snow.
Apr. 14	Early a. m.	6 p. m	1	----	----	----	1	----	----	Lt. snow and lt. rain.
Apr. 18	Early a. m.	9 a. m	----	8	----	----	1	----	----	Lt. rain; sparks.
Apr. 19	5:45 p. m...	5:50 p. m...	----	8	----	----	1	----	----	Lt. rain, tr.
Apr. 20	Early a. m.	10:45 a. m..	1	----	----	----	1	----	----	Lt. snow.
Apr. 20	4:40 p. m...	8 p. m	----	6	----	----	1	----	----	Do.
Apr. 21	11:02 a. m..	12 m	----	2	----	----	1	----	1	Lt. snow, tr.
Apr. 24	9:20 a. m...	9:45 a. m...	----	$\frac{1}{4}$	----	----	1	----	----	Lt. snow.

TABLE O.—*Potential on days on which precipitation occurred at Ithaca, N. Y., October*, 1887, *to August*, 1888—Continued.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative observed.	No observation.	Negative.	No negative observed.		
1888.										
May 1	Early a. m.		....	8	....	1	....	....	....	Lt. rain, tr.
May 2	Early a. m.		....	8	....	1	....	....	....	Lt. rain.
May 8	8 a. m	12:30 p. m..	1	....	....	....	1	....	....	Do.
May 10	1:55 p. m...	4:20 p. m...	....	....	1	....	1	....	....	Heavy rain, thunder.
May 12	11:15 a. m..	12:40 p. m..	....	¼	....	....	1	....	....	Lt. rain, thunder.
May 12	4:10 p. m...	4:40 p. m...	....	3	....	....	1	....	....	Lt. rain.
May 13	6:35 p. m...	7:30 p. m...	....	9	....	1	....	....	....	Do.
May 14	8:30 a. m...	12:30 p. m..	1	....	....	...	1	....	1	Do.
May 15	11:30 a. m..	1:55 p. m...	....	3	....	....	1	....	....	Lt. rain and hail; sparks.
May 16	8:55 a. m...	2:50 p. m...	1	....	....	....	1	....	1	Lt. rain.
May 18	10:30 a. m..	4:15 p. m...	....	2	....	....	1	....	....	Do.
May 25	4:35 p. m...	D. n.....	....	....	1	....	....	1	....	Lt. rain; no sp'l obs.
May 27	7:45 p. m...	8:15 p. m...	....	9	....	1	....	....	....	Lt. rain.
May 28	8:30 a. m...	9:25 a. m...	1	....	....	....	1	....	....	Do.
May 29	9:50 a. m...	10:30 a. m..	....	1	....	....	1	....	1	Do.
May 31	3:31 p. m...	4:07 p. m...	....	6	....	....	1	....	....	Lt. rain; thunder.
June 2	2:25 p. m...	3:30 p. m...	....	6	....	....	1	....	....	Lt. rain; thunder; sparks.
June 11	2 p. m	3:15 p. m...	....	5	....	....	1	....	....	Lt. rain, tr.
June 15	7 a. m	9:30 a. m...	1	....	....	....	....	1	....	Lt. rain; no sp'l obs.
June 23	12:30 p. m..	2:45 p. m...	....	½	....	....	1	....	....	Hy. rain; thunder.
June 24	2:50 p. m...	4:10 p. m...	....	2	....	....	1	....	....	Lt. rain; thunder.
June 26	8 a. m	9:10 a. m...	1	....	....	....	....	1	....	Lt. rain; no sp'l obs.
June 28	All day.		1	....	....	....	....	1	....	Lt. rain.
June 29	.....	10:10 a. m..	1	....	....	....	....	1	....	Do.
July 5	12:15 p. m..	12:55 p. m..	....	2	....	....	1	....	1	Lt. rain; thunder.
July 8	10 p. m	D. n.....	....	10	....	1	....	....	....	Lt. rain.
July 18	2:30 p. m...	5:30 p. m...	....	6	....	....	1	....	1	Do.
July 19	2:35 p. m...	3:40 p. m...	....	6	....	....	1	....	1	Hy. rain.
July 26	1:05 p. m...	D. n.....	....	1	....	....	1	....	....	Lt. rain.
July 31	2:10 p. m...	2:55 p. m...	....	2	....	....	1	....	1	Do.
Aug. 4	5:30 p. m...	7:15 p. m...	....	½	....	1	....	....	....	Lt. rain; thunder.
Aug. 11	12 m	12:55 p. m..	....	....	1	1	....	....	....	Lt. rain; no sp'l obs.
Aug. 12	3 a. m	10 a. m	1	....	....	....	1	....	....	Lt. rain.
Aug. 13	8:35 a. m...	10 a. m	1	....	....	....	1	....	....	Do.
Aug. 17	8 a. m	10:45 a. m..	1	....	....	....	....	1	....	Lt. rain; no sp'l obs.
Aug. 21	2:20 p. m...	D. n.....	....	....	1	....	....	1	....	Do.
Aug. 22	.....	10:20 a. m..	1	....	....	....	....	1	....	Do.
Aug. 23	4 p. m	4:15 p. m...	....	3	....	1	....	....	....	Do.
Aug. 31	7 p. m	11 p. m	....	4	....	1	....	....	....	Do.
Total (146)			49	68	29	21	74	51	18	

Storms.	Number.	Before.			During.			Negative after.
		No observation.	Negative first observed.	No negative observed.	No observation.	Negative.	No negative observed.	
Rain	66	18	42	6	16	38	12	....
Snow	64	24	21	19	4	22	38	....
Sleet	4	2	0	2	1	2	1	....
Sleet and snow	2	0	2	0	0	2	0	....
Rain and snow	4	2	2	0	0	4	0	....
Rain and sleet	5	3	0	2	0	5	0	....
Rain and hail	1	0	1	0	0	1	0	....

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887.

Date.	Remarks.
1885.	
Jan. 1	No record in a. m.; variable positive and negative from 12 m. to 1:30 p. m.; strong positive from 3 to 4 p. m.; then steady positive; sleet from 12 m. to 1:20 p. m.; lt. snow from 2:40 to 4:25 p. m.
Jan. 4	Negative from 7 a. m. all day; lt. snow b. 7 a. m. changed to sleet 9:15 a. m., changed to rain 10:20 a. m., changed to sleet 1:30 p. m., e. 6 p. m.
Jan. 5	Negative from midnight to 1 p. m.; then positive except slight negative at 10 p. m.; lt. rain b. 7:25 p. m.
Jan. 6	Positive in a. m. except negative from 2 to 4 a. m. and from 9 to 9:30 a. m.; variable strong positive and negative from noon until 7 p. m.; then positive; lt. rain all day, e. 7:10 p. m.
Jan. 11	Negative from 10 a. m. to 2 p. m. and from 10 p. m. to midnight; positive at other times; lt. rain from 12:20 to 2:40 p. m. and from 6:40 p. m. to midnight.
Jan. 12	Variable negative, with occasional positive, from midnight to 2 p. m.; then positive; rain e. 5:50 a. m.; lt. rain from 12:20 to 12:55 p. m.
Jan. 15	Strong negative from 5:30 a. m. to noon; no record in p. m.; sleet b. early a. m. changed to rain 7:15 a. m., e. 2:15 p. m.; lt. rain from 5:40 to 8:15 p. m.
Jan. 16	No record in a. m.; from noon positive all day except slight negative at 1 and 4 p. m.; lt. rain b. early a. m., e. 10 a. m., followed by dense fog all day.
Jan. 17	Negative from 1 to 6 a. m.; then weak negative and positive all day; lt. rain b. and e. early a. m., followed by clearing weather, with gale, NW. winds.
Jan. 23	Variable positive from midnight to 9 p. m. except occasional negatives from 10 a. m. to 12 m.; variable positive and negative from 9 p. m. to midnight; lt. snow b. 6:40 p. m. changed to sleet 9:30 p. m.
Jan. 24	Negative from midnight to 7 a. m.; then positive, with occasional negative, until 3 p. m., then positive; sleet e. 9:40 a. m.; snow and sleet covered ground 2 inches.
Jan. 28	Positive until 6 a. m.; then strong variable positive and negative until 9 a. m.; then negative until noon; then strong positive until 8 p. m.; lt. snow b. early a. m., e. 9:20 a. m.
Feb. 1	Negative from 12 mid. to 1 a. m. and at 4 a. m.; no record from 4 a. m. to noon; then positive; lt. snow before sunrise; cloudy, followed by fair weather.
Feb. 4	Steady positive until 6 a. m.; then negative and positive until 8 a. m.; then positive until 10:30 a. m.; then negative and positive until 3 p. m.; strong variable positive and negative from 5 to 9 p. m.; then positive until midnight, except slight negative at 11:30 p. m.; cloudy, lt. rain from 6:30 to 7:50 p. m.
Feb. 5	Slight negative at 2:30 and 4:30 a. m.; then positive until 6 p. m.; then variable positive and negative until midnight; lt. rain b. and e. before sunrise; lt. rain b. 9:15 p. m. changed to moist snow at 10:30 p. m.
Feb. 6	Positive until 5:30 a. m.; negative 5:30 to 7 a. m.; zero 7 a. m. to noon; positive in p. m.; lt snow during the night e. before sunrise, 1 inch.
Feb. 9	Lt. rain b. 10:05 a. m. changed to hy. rain 6 p. m. continued until midnight, with hy. thunder and lightning from 10 to 11 p. m.
Feb. 10	Positive from noon to 7 p. m., then negative to midnight; rain e. early a. m.; lt. snow b. 7:50 a. m. continued at intervals until 10:20 a. m.; NW. gale winds in p. m.
Feb. 13	Variable positive and negative from 11 a. m. to 3 p. m.; positive at other times; lt. snow from 11:30 a. m. to 4:35 p. m., 2 inches.
Feb. 14	Variable positive until 3 p. m.; then variable positive and negative until 9:15 p. m.; then steady positive; lt. snow b. 1:15 p. m. continued all day.
Feb. 15	Positive all day; lt. snow ended shortly after midnight.
Feb. 16	Negative from midnight to 5 a. m.; then strong variable positive and negative until 9:30 a. m.; then positive; hy. rain during the early morning, followed by snow from 9:50 to 11:15 a. m.; NW. gale.
Feb. 17	Positive until 9:30 p. m.; then strong variable positive and negative until 11:30 p. m.; cold wave; hy. snow b. 9 p. m.
Feb. 18	Positive all day except slight negative at 5 to 6 a. m. and 7 to 7:30 p. m.; lt. snow ended early a. m.
Feb. 24	Strong variable positive until 8:30 p. m.; then strong variable positive and negative; lt. snow b. 3:30 p. m. continued at night.
Feb. 25	Strong variable positive and negative until 5:30 a. m.; then variable positive; hy. snow continued all night, e. 6:25 a. m., 7.5 inches.
Feb. 26	Variable positive all day except slight negative at 4 to 5 a. m. and from 6:45 to 8 p. m.; lt. sleet b. 5:50 p. m. changed to snow 7:30 p. m.
Feb. 27	Positive and negative from 1 to 7 a. m., then positive; lt. snow continued during night ended 10:25 a. m.
Mar. 1	Negative from 6 to 8 a. m.; strong variable positive and negative from 10 a. m. to 9 p. m., then positive; lt. rain at intervals from 10:45 a. m. to 6:20 p. m.
Mar. 2	Steady positive all day; lt. rain before sunrise.
Mar. 7	Positive and negative from 7 to 11 p. m. of 6th; strong positive and negative from 1 to 5 a. m. of 7th; negative at 7 a. m. and 6 to 7 p. m.; positive at other times; lt. snow b. 1:10 a. m., e., before sunrise; lt. snow from 8:50 to 10:10 a. m.
Mar. 8	Negative and positive from 4:30 to 7 a. m.; positive at other times; lt. snow from 6 to 6:45 a. m.
Mar. 12	Strong positive and negative variable from 1:30 to 3:30 a. m. and from 10 to 10:30 a. m.; negative variable from 3:30 to 10 a. m. and from 11 a. m. to 7:30 p. m., then variable positive; lt. rain before sunrise and from 7:50 a. m. to 7:20 p. m., when it changed to snow.
Mar. 13	Variable positive with occasional negative all day; lt. snow fell at intervals all day.
Mar. 14	Negative from 1 to 2 a. m.; positive all day; lt. snow, e. early a. m.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Remarks.
1885.	
Mar. 15	Negative with occasional positve from 8 a. m. to 10 p. m.; strong at 3:30 a. m., 11 a. m., and 4 to 5 p. m.; lt. rain before sunrise and from 3:30 to 3. 45 p. m.; fog from 7:30 to 10 p. m.
Mar. 19	Weak variable positive, except strong variable positive and negative from 8:45 to 10:45 a. m.; lt. snow from 8:25 to 10:45 a. m.
Mar. 22	Variable positive and negative all day; lt. snow from 9:10 a. m. to 2:45 p. m.
Mar. 31	Negative at 6:30 a. m. and variable positive and negative from 2 to 10 p. m.; positive at other times; lt. rain from 5:55 to 8:40 p. m.
Apr. 3	Positive until 7 p. m.; negative until midnight, with strong variations from 10 to 11 p. m.; rain b. 7:50 p. m., continued during night.
Apr. 4	Negative until noon; positive and negative until 3 p. m., then positive; rain during the early morning; lt. sleet from 10:25 to 10:35 a. m.
Apr. 5	Positive until 11:30 p. m.; very strong positive 8 to 9 p. m.; strong variable positive and negative from 11:30 p. m. to 1 a. m. of 6th; lt. rain from 11:30 to 11:50 p. m.
Apr. 7	Positive in a. m.; positive with occasional negative from noon to 6:30 p. m.; negative from 6:30 to 8 p. m., then positive; lt. rain at intervals from 1:40 to 10:20 p. m.
Apr. 8	Negative and positive from midnight to 7 a. m., then positive until noon; lt. rain from 12:50 to 2:15 p. m.; thunderstorm and rain from 3:22 to 5:25 p. m.
Apr. 11	Positive until 1 p. m., then negative and positive until 6 p. m., then steady positive; lt. rain b. 10:10 a. m., changed to snow 10:15 a. m., e. 2:25 p. m.; lt. rain from 3:25 to 3:50 p. m.
Apr. 13	No record in a. m.; negative and positive until 5:30 p. m., then positive; lt. rain from 11:40 to 11:45 a. m.; brisk NW. winds, cloudy.
Apr. 15	Negative at 1 a. m., then positive until 9 a. m., then variable positive and negative until midnight; lt. rain from 10:40 a. m. to 12:20 p. m.; lt. rain b. 3:50 p. m., continued during day.
Apr. 16	Negative and positive until 6 a. m., then weak variable positive; lt. rain, e. early a. m.
Apr. 28	Positive in a. m.; strong negative from noon to 5 p. m., then positive.; lt. rain from 3:10 to 3:55 p. m.
May 1	Strong negative and positive from 11 p. m. of April 30 to 9 a. m. of May 1, then positive to noon; no record in p. m.; lt. rain at intervals from 7:15 a. m. to 4:50 p. m.
May 6	Slight negative at 7:30, 9:30, and 11 p. m. of 5th, and 2 a. m. and 6 to 7:30 a. m. of 6th; also at 7 p. m.; cloudy; lt. SE. winds; lt. rain b. 8:25 p. m.
May 7	Strong negative with occasional positive from 12:30 to 4 p. m., then positive; lt. rain continued, changed to heavy rain in early a. m., e. 4:10 p. m.
May 13	Positive to 3 a. m., then strong negative until 7:30 p. m., then positive; rain from early a. m. to 3:20 p. m.
May 14	Negative and positive from midnight to 7:30 p. m., then positive; lt. rain 6:40 to 7:40 a. m., and from 5:40 to 6 p. m.
May 17	No record in a. m., variable positive in p. m.; lt. rain from 11:15 to 11:20 p. m.
May 20	Negative from midnight to 1 a. m. and from 6:30 to 8 a. m.; positive at other times until 5 p. m., then negative and positive until 10 p. m.; lt. rain from 9:25 to 9:35 p. m.
May 21	Variable positive until 4:30 p. m., then negative and positive until midnight; lt. rain at intervals from 6:43 to 10:20 p. m.
May 22	Positive and negative from midnight to 6 a. m., then strong negative until noon, then positive and negative until 6 p. m., then steady negative; rain b. early a. m., e. 9:40 p. m.; fell in heavy showers during the forenoon.
May 23	Positive from noon to 9 p. m.; steady weak negative at other times; lt. rain began and ended before sunrise.
May 24	Weak steady negative in a. m.; negative and positive from noon to 3 p. m., then positive.; the record does not seem to be good on 23d and 24th.; lt. rain before sunrise, and from 11:10 to 11:15 a. m.
May 25	Zero until 10:30 a. m., then variable positive to 12 m.; lt. rain and thunderstorm began about 11 p. m.
May 26	Variable positive in p. m., with slight negative at 4 p. m.; thunderstorm and rain, e. early a. m.
May 27	Steady positive in a. m.; negative and positive from noon to 4 p. m., then variable positive; lt. rain b. 12:45 p. m. and fell at intervals the rest of the day.
May 28	Variable positive all day, except slight negative from 5 to 5:30 a. m.; lt. rain fell at intervals during the morning; cloudy.
May 29	Steady positive in a. m.; no record from 12 m. to 2 p. m.; negative from 2 to 5:30 p. m., then negative and positive; cloudy, with rain from 9:05 a. m. to 10:35 p. m.
May 30	Negative and positive in a. m.; positive from noon to 6 p. m., then variable negative; cloudy with lt. rain at intervals from early a. m. to 8:40 p. m.
May 31	Variable negative all a. m., except slight positive at 5:30 a. m.; cloudy, with occasional showers all day; lt. thunderstorm from 3:06 to 3:35 p. m., and from 6:55 to 7:55 p. m.
June 4	Positive in a. m.; lt. rain and thunderstorm from 3:30 to 5 p. m.
June 5	Heavy thunderstorm and rain, with hail and high winds from 2:35 to 3 p. m.
June 7	Positive in a. m.; lt. rain with lightning from 8:55 to 9 p. m.
June 8	No record from noon to 2 p. m.; negative from 2 to 3 p. m. and at 7 p. m., then positive; lt. rain at intervals from 9:15 a. m. to 5:40 p. m.
June 15	Lt. thunderstorm 6 to 7 p. m.; lt. rain 6:15 to 6:35 p. m.
June 16	Lt. rain 6:40 to 6:43 p. m. and from 7:05 to 8:20 p. m.; thunder from 7 to 8:30 p. m.; silent lightning until midnight.
June 17	Variable positive in p. m.; hy. rain from 12:15 a. m. to 1 a. m., followed by lt. rain until 8 a. m.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Remarks.
1885.	
June 25	Positive until 7 a. m., then negative and positive until 4:30 p. m., then negative to midnight; lt. rain from 9:45 a. m. to 4:10 p. m.
June 26	Steady negative in a. m.; steady positive after 1 p. m.; cloudy, with rain from 9:20 to 9:30 a. m.; SE. winds.
June 27	Variable positive in a. m.; lt. rain from 6:15 to 7:20 a. m. and from 1 to 2. 15 p. m.
June 28	Negative and positive from noon to 5 p. m., then positive; very heavy rain 2:50 to 10:15 a. m.; amount 4.47 inches, of which 4.19 inches fell between 2:50 and 7 a. m.; very severe thunder and lightning accompanied the storm about 4 a. m.
July 2	Strong positive and negative from 11:30 a. m. to 2 p. m.; low positive rest of the time; lt. rain from 12:35 to 1 p. m.
July 5	Positive in a. m.; fair in a. m.; hy. rain and thunderstorm from 2:08 to 6:50 p. m.
July 6	Positive and negative from 12 m. to 2 p. m., then positive; lt. rain from early a. m. to 10:20 p. m.
July 7	Positive until 9 a. m.; then negative until 2:30 p. m.; then positive; lt. rain from 12:50 to 1 p. m., from 9:57 to 10 p. m., and from 10:15 to 10:20 p. m.
July 10	Positive all day except slight negative from 6 to 8 p. m.; lt. rain from 7:10 to 7:20 a. m. and from 12:50 to 1 p. m.; no record during last rain.
July 13	Variable positive all day; lt. rain from 5:08 to 5:13 p. m. and from 7:36 to 7:45 p. m.
July 14	Slight negative midnight to 1 a. m.; strong negative from 3 to 4 a. m.; steady positive at other times; lt. rain b. 12:50 a. m., ended before sunrise.
July 18	Positive in a. m.; lt. rain 8:45 to 9:20 p. m.; thunder 8:30 to 9:30 p. m.
July 20	Variable positive in a. m., with slight negative at 6 a. m.; lt. rain from 11:50 a. m. to 12:16 p. m. and from 2:37 to 2:57 p. m.; silent lightning from 8:40 to 8:50 p. m.
July 25	Lt. rain from 6:52 to 7:08 p. m.; lightning from 8:40 to 9:30 p. m.
July 26	Fair in a. m.; hy. thunderstorm, with rain at intervals, from 3:10 to 8:15 p. m.
July 27	Variable positive in p. m.; lt. rain from early a. m. to 7:20 a. m. and from 1:20 to 1:50 p. m.
July 28	Slight negative to zero until 5 a. m.; variable positive rest of the time; lt. rain 12:50 to 1:10 a. m.
July 29	Slight negative at 5 a. m.; strong positive at 11 a. m.; strong variable positive and negative from 12:30 to 2 p. m.; positive at other times; lt. rain from 11:30 to 11:48 a. m. and from 1:05 to 1:20 p. m.
July 31	Variable positive in a. m.; lt. rain and thunderstorm 3:05 to 3:40 p. m.
Aug. 1	Lt. rain fell during early a. m.; lt. rain 8:25 to 9:10 p. m.; thunder from 8 to 9:30 p. m.
Aug. 2	Lt. rain before sunrise; lt. rain from 8 to 8:45 p. m.; lt. rain b. 10:10 p. m.; thunderstorm b. 6:30 p. m.
Aug. 3	Lt. rain changed to hy. rain during early a. m. and continued at intervals until 7:30 p. m.; amount of rainfall 3.35 inches; the thunderstorm which was prevailing at midnight c. 3 a. m.; a thunderstorm occurred between 4 and 7:30 p. m.
Aug. 4	Variable positive in p. m.; lt. rain during early a. m., followed by clear weather.
Aug. 7	Variable positive until 9 a. m., then strong variable negative, with occasional positive, until midnight; lt. rain b. 8:25 a. m. and continued all day.
Aug. 8	Variable positive all day with slight negative at midnight and at 9:30 to 10 a. m.; lt. rain continued at intervals until 11:25 a. m.
Aug. 12	Variable positive in a. m.; lt. rain from 9:15 to 9:25 a. m., from 10:20 to 10:50 a. m. and from 3:13 to 3:50 p. m., with thunder from 3 to 4 p. m.
Aug. 13	Lt. rain during early a. m.; lt. rain and thunderstorm from 4:05 to 8:10 p. m.
Aug. 14	Steady positive in p. m.; lt. rain during early a. m., followed by fair weather.
Aug. 21	Negative from 6:30 to 8 p. m. of 20th; variable positive on 21st; lt. rain from 8:45 to 9:05 p. m.
Aug. 22	Steady positive in a. m.; lt. rain and thunder from 6 to 7:20 p. m.; lt. rain 9:15 to 10:40 p. m.
Aug. 23	Lt. rain during early a. m.; lt. rain 2:20 to 2:33 p. m.; thunder from 2 to 2:40 p. m.; silent lightning from 6:55 to 8:30 p. m.
Aug. 25	Positive in a. m.; fair in a. m.; hy. rain and thunder from 3:25 to 7:15 p. m.
Aug. 26	Positive in p. m.; lt. rain fell during early a. m., followed by clearing weather.
Aug. 29	Variable positive all day except slight negative at 9 a. m. and 6 p. m.; lt. rain from 5:50 to 6 p. m. and from 7:45 to 9:30 p. m.
Aug. 30	Positive in a. m.; lt. rain from 10:15 to 11:05 p. m.; thunder from 10 to 11 p. m.
Aug. 31	Positive in p. m.; lt. rain during early a. m.
Sept. 4	Positive in a. m.; thunderstorm with lt. rain at intervals from 3:50 to 7:50 p. m.
Sept. 5	Positive from noon to 4 p. m.; then variable positive and negative until 8 p. m.; then positive; lt. rain in early a. m. and from 2:33 p. m., at intervals, until 6 p. m.
Sept. 8	Negative and positive from 3 to 6 a. m.; variable positive rest of the time; lt. rain 4:30 to 7:05 p. m.
Sept. 9	Variable strong positive and negative 1 to 2 a. m., from 12 m. to 2 p. m.; variable positive at other times; lt. rain during early a. m. and from 12:35 to 12:45 p. m.; silent lightning 7:15 to 10 p. m.
Sept. 10	Negative from 1 to 1:45 p. m.; variable positive and negative from 6:30 to 9:30 p. m.; positive at other times; lt. rain 6:25 to 7:30 p. m.
Sept. 11	Negative and positive from midnight to 4 a. m.; then positive until noon; no record in p. m.; lt. rain in early a. m.
Sept. 22	Negative from 2 to 3 p. m., at 6:30 p. m., and from 10 p. m. to midnight; positive at other times; cloudy, with occasional rains all day.
Sept. 23	Low negative from 12 to 1 a. m.; positive rest of the day; lt. rain ended early a. m.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Remarks.
1885.	
Oct. 2	Variable positive and negative from 7 a. m. to noon; lt. rain 6:57 to 7:15 a. m.; lt. rain b. 2:40 p. m., continued rest of day; lt. thunder from 9:10 to 9:45 p. m.
Oct. 3	Positive in p. m., except negative at 9 p. m.; lt. rain e. 6:35 a. m.; lt. rain 8:50 to 9:05 p. m.
Oct. 4	Positive all day; record not good in a. m.; lt. rain at intervals from 6:50 a. m. to 1:35 p. m.
Oct. 6	Positive until 4 a. m.; then negative until 6 a. m.; then strong variable positive and negative until 3 p. m.; then positive, except slight negative at 9:15 p. m.; lt. rain from early a. m. to 2:47 p. m.
Oct. 8	Positive until 6 a. m.; then strong variable negative, with occasional positive, until 2 p. m.; then positive; lt. rain from 6:45 a. m. to 1:43 p. m.
Oct. 12	Variable positive until 6 p. m.; then strong variable negative until midnight; lt. rain b. 4:05 p. m. continued during night.
Oct. 13	Strong variable negative until 7 a. m.; then variable positive; rain continued during a. m., e. 1:43 p. m.
Oct. 14	Positive all day, except negative from 7 to 8 p. m.; lt. rain from 6:35 to 7:20 p. m.
Oct. 21	Strong negative from 4:30 to 10 a. m.; positive at other times; hy. rain b. early a. m., e. 11:45 a. m.; amount, 1.48 inches.
Oct. 23	Variable positive all day; lt. rain 8:15 to 8:22 p. m.
Oct. 29	Variable positive in a. m. except slight negative at 11 a. m.; lt. rain during the day, increasing to hy. rain after dark; thunder and lightning at 5:45 to 6 p. m.
Oct. 30	Positive in p. m., except negative 6:30 to 7:30 p. m.; rain ended early a. m.; lt. rain 11:55 a. m. to 12:50 p. m. and from 5:05 to 7:25 p. m.
Nov. 1	Positive in a. m.; strong variable positive and negative from 4:30 p. m. to midnight; lt. rain b. 6:20 p. m. changed to hy. rain about sunset.
Nov. 2	Strong positive and negative until 4:30 a. m.; then positive; rain ended early a. m.
Nov. 5	Variable positive all day, with slight negative from 11:30 p. m. to midnight; lt. rain from 9:45 to 10:30 p. m.
Nov. 6	Positive all day; lt. rain in early a. m.
Nov. 7	Negative and positive from 3:30 to 5:30 a. m. and from 3 to 4 p. m.; positive at other times; lt. rains at intervals from 3:55 a. m. to 3:53 p. m.
Nov. 8	Negative from 1 to 2:30 a. m.; variable positive and negative from 8 a. m. to 3 p. m.; negative from 10:15 p. m. to midnight; positive at other times; rain b. 12:35 a. m. and continued at intervals all day.
Nov. 9	Strong positive and negative from 1:30 to 6 a. m.; then positive; rain ended early a. m.
Nov. 13	Slight negative at 9:30 a. m.; positive and negative from 2:30 to 4:15 p. m.; positive at other times; lt. rain 11:07 a. m. to 4:35 p. m.
Nov. 18	Slight negative from 2 to 3 a. m.; variable positive rest of the day; lt. rain 9:10 to 9:35 p. m.
Nov. 19	Negative and positive from 11 a. m. to 4 p. m.; variable positive at other times; lt. rain before sunrise; lt. rain 10:55 a. m. to 1:40 p. m.
Nov. 21	Negative from 10 p. m. of 20th to midnight and at 6:30 a. m. to-day; positive at other times; no record from noon to 2 p. m.; lt. rain 10:50 a. m. to 12:35 p. m.
Nov. 22	Positive in a. m.; strong variable positive and negative in p. m.; rain b. 11:30 a. m., continued all day.
Nov. 23	Strong variable positive and negative from 2 to 5 a. m.; positive and negative until 1 p. m.; positive 1 to 7 p. m.; then strong negative to midnight; lt. rain all day, changed to snow 9:10 p. m.
Nov. 24	Negative until 3 a. m.; negative and positive until noon; positive in p. m.; rained all night and ended 11:20 a. m.
Nov. 25	Positive all day; trace of snow 6 to 7:20 p. m.
Nov. 27	Positive all day, except slight negative 2 p. m.; lt. rain 2:50 to 3:15 p. m.
Nov. 28	Variable positive all day, except negative from 8 to 9 a. m.; lt. rain before sunrise.
Nov. 29	Positive in a. m.; negative and positive from noon to 3:30 p. m.; then positive; lt. rain from 10:25 a. m. to 6:40 p. m.
Dec. 1	Variable positive and negative from 6 a. m. to 6 p. m.; lt. rain mist b. early a. m., e. 8:05 p. m.
Dec. 3	Slight negative at 9 and 11 a. m., and 3 p. m.; positive at other times; lt. rain and sleet 11:40 to 11:58 a m.
Dec. 5	Strong positive and negative from 5 to 7 a. m.; slight negative at 8 and 10 p. m.; positive at other times; lt. rain from 5:15 to 7:40 a. m.
Dec. 9	Slight negative 10 to 11 p. m. of 8th; strong variable negative from 11:30 a. m. to 2:30 p. m. to-day; slight negative at 11 p. m.; variable positive at other times; lt. rain before sunrise; hy. rain 11:15 a. m. to 1:50 p. m.; lt. rain 9:43 to 10:20 p. m.
Dec. 13	No record until 10:30 a. m.; then strong negative until 4 p. m.; then strong positive to 10:30 p. m.; then strong negative until 1 a. m. of 14th; rain b. 7:45 a. m. and continued all day.
Dec. 14	Positive after 1 to 11 a. m., except negative at 4:30 a. m.; strong negative 12 m. to 3 p. m.; then steady positive; rained until 3 p. m.
Dec. 23	Slight negative 10 p. m. of 22d and 7 a. m. to-day; then positive to 3:30 p. m.; then negative and positive to midnight; lt. rain 6:35 to 6:50 p. m.
Dec. 31	Strong variable negative from 4 a. m. to noon; positive in p. m.; lt. rain from early a. m. to 12:45 p. m.
1886.	
Jan. 4	Steady positive from 9 p. m. of 3d to 12:30 a. m. of 4th; then variable positive and negative until 6 a. m.; then strong variable negative, with an occasional weak positive, until 10 p. m.; then slowly rising positive until midnight; lt. rain b. 12:10 a. m., increasing to a heavy rain after daylight, e. 10:20 p. m.; SE. gale winds.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Remarks.
1886. Jan. 5	Nearly steady positive all day; a trace of snow from 11 a. m. to 12:40 p. m., followed by colder, clearing weather.
Jan. 6	Weak variable positive all day; a trace of snow from 12:05 to 12:35 p. m., followed by clear weather and a cold wave.
Jan. 8	Variable positive until 5:30 p. m.; then variable positive and negative until 8 p. m.; then strong, rapidly varying positive and negative until 5 a. m. of 9th; lt. snow b. 6:30 p. m., soon changed to hy. snow, continued all night.
Jan. 9	Strong variable positive and negative from midnight until 5 a. m.; then negative until 7 a. m.; then variable positive until 5 p. m.; then variable positive and negative until midnight; hy. snow d. n., e. 9:45 a. m.; amt. of snow on 8th and 9th, 9 inches; heavy gales; barometer 29 inches.
Jan. 10	Collector frozen during the night; negative from 10 a. m. to noon; no record after noon; SW. to NW. gales; a trace of snow from 6:10 to 7:55 p. m.; precipitation on the 16, 17th, 18th, 19th, 21st, 24th, and 25th, no record; collector frozen.
Jan. 25	No record in a. m.; variable positive from noon to midnight, except from 8:30 to 10 p. m., when it was variable positive and negative; lt. rain b. 8:30 a. m., e. 10:25 p. m.
Jan. 27	Variable all day; positive until 10:30 a. m.; then negative until noon; positive from 12 m. to 2:30 p. m. and from 4 to 8:30 p. m.; negative from 2:30 to 4 p. m. and from 8:30 to midnight; lt. rain b. 7:55 a. m., continued all day.
Jan. 28	Strong variable positive all day, except negative at 6 to 6:15 a. m., 4:30 to 5 p. m., and from 10 p. m. to midnight; lt. rain continued all day.
Jan. 29	Variable positive until 7 a. m.; zero until noon; positive in p. m.; lt. rain e. 8:50 a. m.
Jan. 30	Negative from 1:30 to 6 a. m.; then positive until midnight; lt. rain b. 1:10, change to snow 7:45 a. m., e. 2:10 p. m.
Jan. 31	Lt. snow from 10:30 to 10:55 a. m. and from 7:50 to 10:10 p. m.; no record.
Feb. 3	A rising positive potential from 1 to 6 a. m.; then a very strong variable positive until 8 a. m.; then variable positive and negative until 5 p. m.; then weak negative until 10 p. m.; then strong variable positive until midnight; hy. snow began in the early a. m., 13 inches fell by midnight.
Feb. 4	Strong variable positive from midnight to 4 a. m.; then variable negative and occasional positive until noon; no record in p. m.; snow continued during the night; e. 12:15 p. m.; total amount 15 inches, NW. gale.
Feb. 10	Strong variable positive all day, except negative from 9 to 9:15 p. m.; lt. rain b. 10:25 p. m.
Feb. 11	Variable weak positive and negative from midnight until 6 a. m.; then strong variable negative until 4 p. m.; then variable positive until midnight with slight negative at 10 p. m.; rained all day; very heavy rain in the morning.
Feb. 12	Variable positive in a. m.; no record in p. m.; rained all day, e. 9:10 a m. of the 13th; no record on 13th.
Feb. 15	Negative from 6:15 to 6:30 a. m.; variable strong positive and negative from 4:15 to 5:30 p. m.; variable positive the rest of the day; lt. rain from 4:15 to 5:05 p. m.
Feb. 23	Negative at 8 a. m.; weak variable positive and negative from 12 m. to 3 p. m.; strong from 3 to 4 p. m.; positive rest of the time.; lt. rain from 2:25 to 2:40 p. m.
Feb. 25	Steady positive from midnight to 4:30 a. m.: then very strong positive and negative until 4:30 p. m.; variable positive until 9 p. m.; then variable strong positive and negative until midnight; hy. rain during the greater part of the day.
Feb. 26	Variable positive from midnight to 5. a. m.; then variable negative until 7 a. m.; then variable positive until noon; variable negative after noon; colder, NW. gale winds; lt. snow from 7:15 to 9:50 a. m.
Mar. 8	Steady positive until 4 a. m.; then variable strong positive and negative until 3 p. m.; then variable positive until midnight, except negative from 10 to 10:30 p. m.; lt. snow b. before daylight, e. 11:40 a. m.; amount 2 inches.
Mar. 12	Weak positive until 7:30 a. m.; strong variable negative from 8 a. m. to 3 p. m.; then weak variable positive and negative until 8 p. m.; then weak positive until midnight; lt. rain and sleet b. 8:12 a. m., e. 1:40 p. m.
Mar. 13	Weak positive until 7:30 a. m.; weak negative then until noon; then weak positive; lt. rain at intervals from 7:50 to 11:15 a. m.
Mar. 18	Variable positive until 8:30 p. m.; strong variable positive and negative from 8:50 to 10 p. m.; weak positive and negative from 10:20 p. m. to midnight; lt. rain from 8:20 to 9:15 p. m.
Mar. 19	Strong variable positive and negative from 1 to 8 a. m.; weak positive and negative rest of the day; lt. rain before sunrise; cloudy, with E. winds.
Mar. 20	Variable positive and negative all day, with very high and rapid variations from 7 to 11 p. m.; lt. rain b. 8:50 a. m., and continued all day.
Mar. 21	Variable positive and negative from midnight to 3:30 a. m. and from 6 to 7 a. m.; then variable positive until 7 p. m.; strong positive from 7 to 8 p. m.; then strong negative until 10:15 p. m.; then positive; lt. rain during the night e. 7:10 a. m.; lt. rain from 7:15 to 9:20 p. m.
Mar. 22	Variable negative from 10 a. m. to 4 p. m.; variable positive rest of the day; lt. rain before sunrise; brisk W. to NW. winds.
Mar. 26	Variable positive and negative until 9 a. m.; then strong negative until noon; then strong variable positive and negative until midnight; rain b. 8:50 a. m. and continued all day.
Mar. 27	Strong variable positive and negative all day; chiefly negative in a. m.; rain continued all night and day; e. 9:40 p. m.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Remarks.
1886.	
Mar. 28	Variable positive and negative from midnight to 2 a. m.; then positive all day.; lt. rain b. and e. d. n.
Mar. 29	Variable positive and negative all day; rain all day; lt. E. winds.
Mar. 30	Strong negative from 7 to 9 a. m.; strong variable positive and negative from 3 to 9 p. m.; variable positive and negative at other times during the day; rained all day.
Mar. 31	Weak variable negative with an occasional positive all day; lt. rain with occasional heavy showers all day.
Apr. 3	Variable positive and negative all day; lt. rain from 6:35 to 7:10 a. m.; cloudy, with northerly winds.
Apr. 4	Negative during a. m.; no record in p. m.; lt. rain b. early a. m., and continued all day.
Apr. 5	No record in a. m.; variable strong negative and positive from noon to midnight; rained all day.
Apr. 6	Strong variable negative, with occasional positive from midnight to noon; weak positive from noon to midnight, except negative from 7 to 8 p. m.; lt. rain during the night and morning, e. 12 m.
Apr. 7	Variable positive all day, except negative from 7 to 8 a. m. and from 4:30 to 7 p. m.; lt. rain from 12:35 to 12:45 p. m. and from 4:45 to 7:10 p. m.
Apr. 11	Weak variable positive and negative from 2 to 8 a. m. and from 8 p. m. to midnight; weak positive rest of the time; lt. rain from 7:50 to 8:15 a. m.; brisk E. winds.
Apr. 12	Variable positive and negative from midnight to 9 a. m.; then strong positive until 6 p. m.; then zero until midnight; dense fog in morning; lt. rain from 7 to 9:15 p. m.
Apr. 13	Strong variable negative from midnight to 2 a. m. and from 7:30 to 9 a. m.; then variable positive from 2:30 to 4 p. m.; variable positive in p. m., except a slight negative at 5 and 11:30 p. m.; lt. showers of rain during the morning and afternoon; lt. thunder at 3:27 p. m.
Apr. 16	Strong variable positive all day, except a slight negative at 8:30 p. m.; lt. rain from 10:15 to 11:20 p. m.
Apr. 17	Variable positive all day, except negative at 1 to 1:30 p. m. and 6:30 to 7 p. m.; lt. rain before sunrise.
Apr. 24	Lt. rain and thunderstorm from 5 to 9 p. m.
Apr. 25	Variable positive and negative from 3 to 9 p. m.; positive from 9 p. m. to midnight; lt. rain during the early a. m. and from 3:45 to 4:15 p. m.
June 30	Variable positive and negative from 4 to 8 p. m.; variable positive at other times; lt. rain from 5:20 to 5:35 p. m.
July 1	Variable positive in a. m., except slight negative at 7 a. m.; variable positive in p. m., except occasional negative from 6:30 to 8 p. m.; lt. rain b. 10 p. m.
July 2	Very strong variable negative from 1:30 a. m. to 5:30 p. m.; variable positive after 6 p. m.; rained all night and all day, e. 6:30 p. m.
July 10	Steady positive until 6 p. m., except a strong negative from 6 to 6:30 a. m.; variable positive and negative from 6:30 to 8 p. m.; lt. rain from 8:05 to 8:20 p. m.
July 13	Slight negative at 4 and 7 a. m. and strong variable positive and negative from 9 a. m. to 1 p. m.; steady positive in p. m.; lt. rain from 10:18 a. m. to 1:25 p. m.
July 14	Lt. rain from 10:10 to 10:30 a. m.; thunderstorm and heavy rain from 3:20 to 4:50 p. m.
July 15	Thunderstorm and hy. rain from 6:20 to 10:45 p. m.; amount of rain 2.09 inches; tornado of 50 yards width and 2 miles length passed over city at 7:10 p. m.
July 16	Lt. rain from 12:30 a. m. to noon.
July 18	Steady positive in a. m.; thunderstorm and lt. rain from 10:20 to 10:50 p. m.
July 21	Slight negative at 8 p. m. of 20th; strong variable positive and negative from 1 to 7 a. m.; weak variable positive and negative from 7 a. m. to 3 p. m., then positive until midnight.; heavy rain from 1 to 8:15 a. m.
July 25	Steady positive until 6:30 a. m.; then strong negative and positive until 1:30 p. m.; then steady positive; rain at intervals from 7:08 a. m. to 2:25 p. m.
July 26	Thunderstorm and heavy rain from 4:30 to 11:30 p. m.
July 27	Lt. rain during the morning, followed by clear weather; silent lightning in the evening.
July 31	Hy. thunderstorm and rain from 12:15 a. m , e. before daylight.
Aug. 1	Variable positive and negative from 2 to 3 a. m.; variable positive until noon; cloudy, with light showers all day; silent lightning from 8:30 to 11:30 p. m.
Aug. 2	Steady positive in p. m.; lt. rain during the early a. m., e. before sunrise.
Aug. 7	Strong steady negative from 2:30 to 7:30 a. m.; then steady weak negative until noon; then weak variable positive and negative until 3 p. m.; then positive; hy. rain began early a. m., changed to lt. rain 7:30 a. m., e. 2:20 p. m.; amount 2.21 inches.
Aug. 14	Steady positive all day; trace of rain 7:03 to 7:55 a. m.
Aug. 17	Lt. rain b. d. n. and e. d. n.; thunderstorm and lt. rain from 3:10 to 5:35 p. m.
Sept. 15	No record in a. m.; variable positive and negative from 12 m. to 1 p. m.; then positive until 9 p. m.; then negative; lt. rain at intervals all day.
Sept. 16	Negative from midnight to 7 a. m.; then positive and negative until noon; then positive; lt. rain during the night and a. m.; clear in p. m.
Sept. 19	Positive until noon; hy. rain and thunderstorm from 4:35 to 5:25 p. m.; lt. rain and thunderstorm from 9:30 to 9:50 p. m.
Sept. 21	Steady positive all day; lt. rain b. 11:15 p. m.
Sept. 22	Zero from midnight to 9 a. m.; then variable positive until 9 p. m.; then variable positive and negative until 11 p. m.; then positive; lt. rain e. early a. m.; cloudy day; lt. rain from 11:25 to 11:35 p. m.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Remarks.
1886.	
Sept. 29	Variable positive and negative from 11 p. m. of 28th to 4 a. m. of 29th; then strong variable positive and negative until 7 a. m.; then positive all day; rain from 12:48 to 8:45 a. m.
Oct. 14	Zero in a. m.; weak variable positive and negative from noon to midnight; lt. rain from 2:55 to 3:10 p. m. and from 10:50 to 11:31 p. m.
Oct. 21	Strong negative from 7 to 8 a. m.; positive rest of the day; lt. rain from 7:50 to 8:45 a. m.
Oct. 26	Variable positive and negative all day; strong in p. m.; lt. rain at intervals during afternoon and night.
Oct. 27	Variable positive and negative all day; lt. rains at intervals during night and all day.
Oct. 28	Variable positive and negative until 5 a. m.; then positive all day; lt. rain during night, ended before sunrise.
Oct. 29	Positive all day; lt. rain 4 to 4:08 p. m.
Oct. 30	Strong negative from 2 to 5 a. m.; negative from 3 to 4 p. m. and from 11 p. m. to midnight; positive rest of the time; occasional lt. rains during the day.
Oct. 31	Negative from midnight to 1 a. m. and at 4 p. m.; positive at other times; lt. rain in early a. m. and at intervals from 8:50 a. m. to 1:55 p. m.
Nov. 6	Variable positive and negative from 7 to 8:15 a. m.; then positive until 3 p. m.; then strong variable positive and negative until midnight; lt. rain from 7:45 to 8:40 a. m.; lt. rain b. 1:55 p. m., continued all day and night.
Nov. 10	Negative from 4 to 4:30 a. m.; variable positive all rest of the day; lt. rain before sunrise.
Nov. 12	Variable positive and negative from 5 a. m. to midnight; very strong, chiefly negative, in p. m.; lt. rain b. 6 a. m., changing to hy. rain in the afternoon, e. 10:48 p. m.
Nov. 13	Steady positive all day except strong positive at 3 p. m.; lt. snow from 2:10 to 3:15 p. m.
Nov. 17	Slight negative at 2 and 4 a. m. of 16th; then variable positive until 7 p. m. of 16th; then variable positive and negative until noon of 17th; then positive; lt. rain during the greater portion of the day.
Nov. 18	Strong variable positive and negative from 6:30 to 8:30 a. m.; steady positive the rest of the day; hy. rain from 7:25 to 9:20 a. m., followed by clearing weather.
Nov. 22	Variable positive until 5:30 p. m.; then variable positive and negative until midnight; lt. rain b. 9:45 p. m.
Nov. 23	Negative from midnight to 6 a. m. and from 8:30 to 9:30 p. m.; variable positive rest of the time; cloudy day, with rain in the morning and at night.
Nov. 24	Negative from 2:30 to 4 a. m.; positive rest of the time; lt. rain in the early morning.
Nov. 25	Steady positive until noon, except a slight negative at 2:30 and 4 a. m.; strong variable positive and negative from noon to 7 p. m.; then positive; lt. rain b. early a. m., changed to hy. rain at 1:30 p. m., e. 7:20 p. m.; a waterspout on bay at 3 p. m.
Nov. 30	Variable positive and negative from 8 p. m. of 29th to 4 a. m. of 30th; then positive until noon; then strong variable positive and negative until 3 p. m.; then positive; lt. rain from 12:10 to 3:30 p. m.
Dec. 4	No record in a. m.; positive in p. m. except a slight negative at 8 p. m.; lt. snow b. 2:05 p. m., continued at night.
Dec. 5	Strong variable positive and negative from midnight to 2:30 a. m. and from noon to midnight; lt. snow continued until 5:15 p. m.
Dec. 6	Variable positive and negative from midnight to 1 p. m.; then positive until 8 p. m.; then negative; lt. snow from 7:35 to 8:10 a. m.; lt. rain b. 11:50 a. m., changed to snow 4:25 p. m., e. 7 p. m.; lt. snow b. 11:10 p. m.
Dec. 7	Negative in a. m.; positive in p. m.; snow continued until 12:30 p. m.
Dec. 12	Positive in a. m.; variable positive in p. m., with slight negative at 8 and 10 p. m.; cloudy, with lt. rains, during the greater part of the day.
Dec. 13	Variable positive, with negative from 7 to 9 a. m.; lt. rain e. 9:30 a. m.
Dec. 15	Zero in a. m.; strong variable positive and negative until 9 p. m.; positive 9 to 11 p. m.; negative 11 p. m. to 12 mid.; lt. rain all day, changed to snow 5:10 p. m., e. 10:50 p. m.
Dec. 16	Slightly negative, nearly zero, all morning; negative from 12 to 3 p. m.; then positive; lt. snow during the early morning, followed by clear weather.
Dec. 18	Negative from 12:30 to 4:30 a. m.; then positive until 7 a. m.; then strong variable negative, with an occasional positive, until 6:30 p. m.; then positive; rain began before sunrise and fell steadily until 7:30 p. m.
Dec. 22	Positive until 10 a. m.; then negative, with an occasional positive, until 7 p. m.; then steady positive; lt. rain from 4:15 to 7:10 p. m.
Dec. 23	Variable positive, with an occasional negative, from 1 p. m. to midnight; fair in a. m.; lt. rain from 12:55 p. m. at intervals until midnight.
Dec. 24	Variable positive, with an occasional negative, from midnight to 8 a. m.; then positive until 7 p. m.; then strong negative until 9 p. m.; then zero until midnight; lt. rain at intervals all day until 9:15 p. m.
Dec. 26	Steady positive in a. m.; variable positive and negative from noon until 9 p. m., with strong variations from 4:30 to 5:30 p. m.; lt. snow b. 1:25 p. m., changed to hy. snow at sunset, e. 6:20 p. m.
Dec. 29	Variable positive until 8 p. m.; then negative and positive until midnight; lt. snow b. 9:45 p. m.
Dec. 30	Negative from 1:45 to 2:15 a. m.; then positive until 12 m.; then variable weak positive and negative until midnight; lt. snow at intervals all day.
Dec. 31	Strong negative from 12:30 to 5 a. m.; then positive and negative until midnight; strong after 8 p. m.; snow changed to rain shortly after midnight and continued all day.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Remarks.
1887.	
Jan. 1	Rapid vibrations from positive to negative from 8 p. m. of Dec. 31 to 1 a. m. of Jan. 1; then variable positive and negative until 4 a. m.; positive until 6 a. m.; negative until 11 a. m.; then steady positive until midnight; rain fell steadily during the early morning, e. 9:15 a. m.; lt. flurry of snow 12:25 to 12:35 p. m.
Jan. 9	Steady positive in a. m.; variable positive in p. m.; lt. snow b. 11:30 a. m.; changed to sleet at 9:50 to 10:15 p. m.; e. early a. m. of 10th; variable positive during the night.
Jan. 13	Variable positive to negative from 6 to 8 a. m.; then positive until 7 p. m.; variable negative until 10 p. m.; positive until 11:30 p. m.; variable negative, with occasional positive, until 6 a. m. of 14th; lt. rain b. 6:55 p. m., e. early a. m. of 14th.
Jan. 17	Variable positive from 6 to 10 a. m., with a slight negative at 7 and 9 a. m.; variable positive and negative from 10 a. m. to 5 p. m.; steady positive until midnight; lt. rain b. 10:55 a. m., e. 4:40 p. m.
Jan. 24	Variable high positive from 3 to 5 a. m.; then high variable positive to negative until 1:30 p. m.; then variable positive until 3 p. m.; then steady positive until midnight; lt. rain b. early a. m.; changed to snow at 11:45 a. m., e. 2:50 p. m.
Jan. 26	Negative from 8 to 9:30 a. m.; variable positive the rest of day; lt. rain from 8:50 to 9:30 a. m.; lt. snow from 6:50 to 9:35 p. m.
Jan. 29	Steady positive in a. m.; strong variable positive and negative from 9 a. m. to 5:30 p. m.; then positive until midnight; lt. rain from 9:30 a. m. to 5:30 p. m.
Feb. 2	Low variable positive, with an occasional negative during the night; with a sudden change to high negative at 5:15 a. m.; then a gradually falling negative until 7 a. m.; then steady weak negative until noon; then variable positive and negative until early a. m. of 3d; snow and sleet in a. m., followed by rain, which fell at intervals during the day.
Feb. 3	Variable positive and negative until 6 a. m.; then variable positive until 3 p. m.; then variable strong positive and negative until 5 p. m.; then positive until midnight; lt. rain during the early morning and from 2:50 to 4:35 p. m.
Feb. 5	Zero potential at 1:30 a. m.; then steady positive until 8 a. m.; then variable positive until 3 p. m.; variable weak positive to negative 3 to 6 p. m.; then weak positive until midnight; lt. snow b. 8:50 a. m.; changed to rain 3:35 p. m.; changed to sleet 6:55 p. m., e. 7 p. m.; lt. rain b. 10:35 p. m.
Feb. 6	Negative at 2 and 4 a. m.; positive until noon; then variable positive and negative until 2 p. m.; then variable positive until midnight, with negative from 5:15 to 5:30 p. m.; lt. rain, continued all night and all day.
Feb. 7	No record in a. m.; variable positive in p. m., with negative for 5 minutes at 1:30 p. m.; lt. rain e. 8:20 a. m.; lt. rain from 5:45 to 9:40 p. m.
Feb. 8	Variable positive all day, with zero potential at 5 a. m., 9:30 a. m., and 3:30 p. m.; negative from 7 to 8 p. m.; lt. rain b. early a. m.; rained all day, e. at night.
Feb. 10	Variable positive all day, with negative from 6 to 7:30 p. m.; lt. rain 5:30 to 8:35 p. m.
Feb. 11	Weak variable positive and negative from 7:30 to 9 a. m.; zero potential all afternoon, probably due to gale causing collector to ground itself against the building; lt. rain from 3 to 5:30 p. m.
Feb. 14	Variable positive from 6:30 to 9 a. m. and all afternoon; variable positive and negative from 10 p. m. to midnight; lt. snow b. 6:15 p. m.; changed to rain at 10:40 p. m.
Feb. 15	Strong variable negative from midnight to 8 a. m.; then variable positive until 6 p. m.; then variable positive and negative until midnight.; rained all night, e. 8:15 a. m.
Feb. 18	Negative from 2 to 2:30 a. m.; steady positive until 6 a. m.; then variable positive and negative until noon; no record in the afternoon; lt. rain b. 7:45 a. m.; changed to heavy rain, hail, and thunderstorm in late p. m.
Feb. 20	Steady positive until 11 a. m.; then variable positive and negative until 6:30 p. m.; then positive until midnight; lt. rain b. 11:45 a.m.; then changed to snow, and during the rest of the day rain, sleet, and snow fell at intervals; e. early a. m. of 21st.
Feb. 23	Strong variable positive all day, except negative at 4:45 p. m., 6 p. m., 7 to 7:15 p. m., and 9 to 9:30 p. m.; lt. snow b. 3:30 p. m.; changed to rain at 7:30 p. m.; continued during the night.
Feb. 24	Strong variable negative from 1 to 3:30 a. m.; then steady positive all day; rain e. before sunrise.
Feb. 26	Steady positive from midnight to 6:30 a. m.; then strong variable positive and negative until 10:15 p. m.; then steady positive; heavy snowstorm b. about 5 a. m.; changed to rain at 11 a. m.; e. 9:30 p. m.
Feb. 27	Steady positive all day, except strong variable positive from 7 to 9 p. m.; lt. flurry of snow from 7:50 to 8:15 p. m.
Mar. 3	Potential low and variable from positive to negative all day; rain and sleet 4:45 to 6 p. m.; sleet 10:30 to 11 p. m.; rain 11 p. m. and d. n.
Mar. 4	Potential, no record during morning; positive variable during afternoon; negative 8:30 to 8:40 p. m.; rain continued from 3d; turned to snow early a. m. to 1:50 p. m.
Mar. 5	Potential variable positive until 2:40 p. m.; strong variable from positive to negative, chiefly negative, 2:40 to 7 p. m.; variable positive 7 to 10 p. m.; variable positive to negative 10 p. m. to midnight; snow 1:20 to 3:30 p. m.; sleet 3:30 to 7 p. m.; rain 7 p. m. to mid.
Mar. 6	Potential variable positive to negative, chiefly negative, 12:01 to 2 a. m.; variable positive 2 to 9:45 a. m.; strong variable positive to negative 9:45 a. m. to 6:45 p. m.; variable positive 6:45 p. m. to midnight; rain continued from 5th; e. early a. m.; threatening rest of day.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Remarks.
1887.	
Mar. 7	Potential variable positive 12:01 to 4:30 a. m.; strong variable positive to negative 4:30 to 10:30 a. m.; high variable positive 10:30 a. m. to midnight; rain early a. m. to 2:25 p. m.
Mar. 9	Potential variable positive, with occasional negative, from 7 p. m. on 8th to 1 a. m. on 9th; variable positive 1 a. m. to 1 p. m.; strong negative, with occasional positive, 1 p. m. to mid.; rain during afternoon and night.
Mar. 10	Potential variable positive to negative from mid. to 5 a. m.; low positive and variable during rest of day; rain mid. to early a. m.
Mar. 13	Potential positive mid. to noon; variable positive 1:30 to 9 p. m.; strong variable positive to negative, chiefly negative, 9 p. m. to 2 a. m. on 14th; rain 11:10 to 11:25 p. m.
Mar. 17	Potential positive mid. to 8 a. m.; variable positive to negative 7 to 9:45 a. m.; variable positive 9:45 a. m. to 4:15 p. m.; variable positive to negative 4:15 to 4:30 p. m.; variable positive 4:30 to mid.; snow, occasional light snow, after 10:45 a. m.
Mar. 18	Potential variable positive midnight to noon and 5 p. m. to mid.; variable positive to negative noon to 5 p. m.; snow, light flurries, during a. m.
Mar. 21	Potential variable positive until 5:45 p. m.; strong variable positive to negative 5:45 p. m. to midnight; rain 3:10 to 9:45 p. m.; snow 9:45 p. m. to mid.
Mar. 22	Potential strong variable positive to negative mid. to 11 a. m.; low positive rest of day; snow mid. to early a. m.; rain early a. m. to 11 a. m.
Mar. 24	Potential variable positive until 10:20 p. m., excepting negative for a few minutes about 7:15 and 9:15 a. m., and 9:15 p. m.; strong variable positive to negative 10:20 to 11:30 p. m.; positive 11:30 p. m. to mid.; lt. rain 10:55 to 11:05 p. m.
Mar. 27	Low variable positive mid. to noon; negative for a few minutes about 7:45 a. m.; variable positive to negative noon to 7 p. m.; strong variable positive to negative 7 p. m. to mid.; rain 7 p. m. to mid.
Mar. 28	Strong variable positive to negative mid. to 6 a. m.; variable positive 6 a. m. to 4 p. m.; strong variable positive to negative 4 to 5:30 p. m.; positive rest of day; rain mid. to early a. m.; snow 4 to 4:50 p. m.
Mar. 31	Strong variable positive, with occasional negative, mid. to 7 a. m.; strong variable positive to negative 7 a. m. to 7 p. m.; variable positive 7 p. m. to mid.; snow 7:45 a. m. to mid.
Apr. 1	Potential low variable positive to negative mid. to 8 p. m.; variable positive 8 p. m. to mid.; lt. snow all day at intervals.
Apr. 2	Potential variable positive all day; snow mid. to 8:35 a. m.
Apr. 4	Potential low variable positive to negative mid. to 10:45 p. m.; strong variable negative 10:45 p. m. to mid.; lt. rain 11:15 to 11:55 p. m.
Apr. 5	Potential strong negative mid. to 1 a. m.; positive 1 to 8 a. m.; low variable positive to negative 8 a. m. to 6 p. m.; low positive 6 p. m. to mid.; snow 4:50 to 4:55 p. m.
Apr. 15	Potential positive and variable mid. to 7 p. m.; strong variable positive to negative 7 p. m. to mid.; thunderstorm 10 to 11 p. m.; rain 11:05 to mid.
Apr. 16	Potential variable positive to negative mid. to 8 p. m.; variations from mid. to 5 a. m. were quite strong; rain mid. to 12:05 a. m.; lt. rain 7:40 to 8 a. m.
Apr. 17	No electrometer record mid. to noon; potential low; positive noon to mid., with negative for a few minutes about 7:20 p. m. and from 10:50 to 11:30 p. m.; lt. rain 6:30 to 7:15 p. m.; rain 11:15 p. m. to mid.
Apr. 18	Potential strong variable positive and negative all day; rain at intervals from mid. during the day to mid.
Apr. 19	Potential low variable positive and negative mid. to 5 a. m.; variable positive rest of day; rain mid. to early a. m.
Apr. 22	Potential variable positive, occasional zero, mid. to 3 p. m.; strong variable positive and negative 3 to 10 p. m.; positive 10 p. m. to mid.; rain 1:35 p. m. to mid.
Apr. 23	Potential variable positive to negative mid. to 11 p. m.; variation strong 6 to 10 p. m.; positive 11 p. m. to mid.; rain at intervals during the day.
Apr. 25	Potential variable positive, with occasional negative, mid. to 1:45 p. m.; strong variable positive and negative 1:45 p. m. to mid.; rain 2:15 p. m. to mid.
Apr. 26	Potential strong variable positive to negative mid. to 4 a. m.; positive 4 a. m. to 5 p. m.; variable strong positive and negative 5 to 7 p. m.; positive 7 p. m. to mid.; rain mid. to early a. m.; rain 6:30 to 7 p. m.
Apr. 27	Potential variable positive to negative 2 to 6 a. m., 5 to 6 p. m., 11 p. m. to mid.; positive rest of day; rain during early a. m.; rain 5:30 to 7 p. m.
Apr. 28	Potential variable positive to negative mid. to 6 a. m.; variable positive 6 a. m. to 2:30 p. m.; strong variable positive and negative 2:30 to 6:30 p. m.; positive rest of day; rain early a. m.; rain 2 to 6:30 p. m.
Apr. 29	Potential low variable positive and negative all day; rain at intervals all day.
May 1	Steady positive all day, except it was variable positive from 9 to 11 p. m.; a trace of rain from 10:25 to 11:15 p. m.
May 5	Variable positive and negative, with sheet lightning, from 7:30 p. m. of 4th to 1 a. m. of 5th; no record from 1 to 9 a. m.; variable positive from 9 a. m. to 3 p. m.; weak variable positive and negative from 3 p. m. to midnight; lt. rain, b. early a. m., continued all day, e. d. n.
May 6	Weak variable positive and negative from midnight to 11 a. m.; strong variable positive and negative from 11 a. m. to noon; no record the rest of the day; lt. rain, with light thunder, from 4:25 to 5:30 p. m.; lt. rain b. 10:30 p. m.
May 7	Rain and thunder on the 7th, 8th, and 9th; no record.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Remarks.
1887.	
May 10	Variable positive from midnight to 5 a. m.; variable positive and negative from 5 to 11 a. m.; variable positive until midnight; lt. rain from 7:40 to 8:15 a. m.
May 24	Steady positive until 9:40 a. m.; then strong variable positive and negative until 9:30 p. m.; then steady positive until midnight; lt. showers fell at intervals after 9:35 a. m.; warm, sultry, and oppressive.
May 27	Steady positive from noon to 4 p. m.; negative from 4 to 4:30 p. m.; then strong positive until 5:30 p. m.; then steady positive until midnight; lt. rain from 4:45 to 4:50 p. m.
May 28	Steady positive from midnight to 7 a. m.; then weak variable positive and negative until noon; no record in the afternoon; lt. rain from 5:30 to 8:20 p. m.
May 31	Variable positive in a. m. and from 1:30 to 5:30 p. m.; variable positive and negative from 11 a. m. to 1:30 p. m.; variable strong negative from 5:45 p. m. to 2:30 a. m. of June 1; lt. rain, with gale, b. 5:30 p. m., continued all night.
June 1	Strong negative from midnight to 2:30 a. m.; strong positive from 2:30 to 3 a. m.; then weak variable positive and negative until 6:30 a. m.; then variable positive all day; hy. rain during the night, e. 7:35 a. m.
June 2	Steady positive from midnight to 5:30 a. m.; strong variable negative from 5:30 to 7 a. m.; then variable positive until noon; lt. rain from 6 to 8 a. m.; thunderstorm, with rain, from 7:35 to 8:20 p. m.; lt. rain, b. 9:50 p. m., e. d. n.
June 6	Steady positive from midnight to 6:30 a. m., except zero at 4:40 and 6:30 a. m.; strong variable positive and negative from 7 a. m. to noon; variable positive from noon to 10 p. m.; zero at 10 p. m.; positive until 11:30 p. m.; then strong negative until 12:30 a. m.; lt. rain from 6:15 a. m. to 1 p. m. and from 11 p. m.
June 7	Weak variable positive and negative from 12:30 to 10 a. m., except from 2 to 4 a. m., when it was strong positive and negative; rain ended during the night; lt. rain from 9:30 to 9:45 a. m.
June 9	Steady positive from midnight to noon; lt. rain from 4:50 to 5:50 p. m., with distant thunder.
June 18	Hy. rain and thunder 4:35 to 4:50 p. m.; amount, 0.54 inch; east of the station the storm was accompanied by hailstones as large as pigeon eggs.
June 19	Lt. rain shortly after midnight; thunderstorm in early a. m.; hy. thunder at station from 7 to 8:30 p. m., and thunder and lightning near station until 10 p. m.; no rain.
June 20	Lt. rain from 7:08 to 7:15 a. m.; thunderstorm, with rain, from 10:45 to 11:30 a. m.; sheet lightning from 8 to 10 p. m.
June 21	Lt. thunderstorm, with rain, from 10:53 to 11:10 p. m.
June 22	Lt. rain at intervals all day; hy. rain b. 6:15 p. m.; thunderstorm just after noon and again in the evening.
June 23	Rain e. 6:50 a. m.; lt. rain from 7.20 to 7:30 a. m., 3:25 to 3:30 p. m., and from 6:35 to 6:40 p. m.
July 5	Variable positive from midnight to 3:40 a. m.; then strong variable negative until 8:30 a. m.; then variable positive and negative until 4 p. m.; variable positive from 4 to 7 p. m,; strong variable positive and negative from 7 to 10 p. m.; then variable positive until midnight; lt. rain from 12:40 to 12:55 a. m.; hy. rain, b. d. n., e. 10:20 a. m.; lt. rain from 1:50 to 3:30 p. m.; distant thunder from 8 to 9 p. m.
July 6	Variable positive from midnight to 3 p. m., except negative at 10 a. m.; strong variable positive and negative from 3 to 4:15 p. m.; variable positive until midnight; lt. rain, b. and e. d. n., 0.02 inch; threatening from 3 to 4 p. m.; sheet-lightning at 9 p. m.
July 9	Negative from 6:30 to 7:30 p. m. of 8th; variable positive from then to 8:30 a. m. of 9th; strong variable positive and negative from 8:20 a. m. to 4:30 p. m.; then variable positive until 8 p. m.; then steady positive to midnight; lt. rain from 6.58 a. m. to 12:25 p. m., 3:30 to 4:15 p. m.; distant thunder and lightning from 11:37 to 11:50 a. m.
July 17	Lt. rain from 3:06 to 4:30 p. m., with thunderstorm.
July 18	A terrific hail and thunderstorm, with rain, from 5:10 to 5:50 p. m. and from 7:35 to 8:15 p. m.; hailstones one-quarter to one-half inch in diameter from 5:20 to 5:35 p. m.
July 19	Thunderstorm and hy. rain from 2:50 a. m., e. d. n.; lt. rain from 10:30 to 10:55 a. m.
July 20	Variable positive in a. m.; strong variable positive and negative from 12 to 1 p. m.; variable positive from 1 to 5 p. m.; weak variable positive to negative from 5 to 8 p. m.; lt. rain from 3:50 to 4:05 p. m.
July 21	Lt. rain, b. d. n., e. 7:30 a. m.; heavy rain 9:35 a. m. to 12:55 p. m., with thunderstorm; amt., 2.70 inches.
July 23	Hy. rain and thunderstorm from 3:18 to 6:15 p. m.; amt., 1.11 inches; lt. rain b. 11:30 p. m.
July 24	Lt. rain at intervals all night, e. 5:30 a. m.; lt. rain 10:40 to 11:10 a. m. and from 8:15 to 9:55 p. m.; from noon to 8 p. m. steady positive; strong variable negative from 8:20 to 9:40 p. m.; then steady positive until midnight.
July 25	A trace of rain in early a. m.; steady positive.
July 26	Hy. rain and thunderstorm from 7:40 to 10:45 p. m., 1.55 inches.
July 27	Variable positive, except from 2:55 to 3:05 p. m , when it was strong negative; lt. rain from 3:04 to 3:06 p. m.
July 29	Trace of rain from 2:25 to 2:35 p. m.; lightning from 7:40 to 10 p. m.
Aug. 2	Variable positive all day; trace of rain from 2:15 to 2:20 p. m.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Before.							During.		After.			Remarks.
		Negative.											
	No record.	10 hours.	6–10 hours.	4–6 hours.	2–4 hours.	1–2 hours.	0–1 hour.	No record.	Negative.	0–1 hour.	1–3 hours.	3 + hours.	
1885.													
Jan. 1	1	....	....	....	....	....	....	....	1	....	....	....	Lt. sleet and snow.
Jan. 4	....	....	....	....	....	....	1	....	1	....	....	....	Snow, sleet and rain.
Jan. 5	....	1	1	....	....	....	....	....	1	....	....	....	Lt. rain.
Jan. 6	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Jan. 11	....	....	....	....	1	1	1	....	1	....	....	....	Do.
Jan. 11	....	....	1	....	....	....	....	....	1	....	....	....	Do.
Jan. 12	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Jan. 12	....	....	....	1	1	1	1	....	1	1	....	....	Do.
Jan. 15	....	....	....	....	....	....	—	....	1	....	....	....	Sleet and rain.
Jan. 16	1	....	....	....	....	....	....	1	....	....	1	....	Lt. rain.
Jan. 17	....	....	....		....	....	1	....	1	1	1	1	Do.
Jan. 23	....	1	1	1	....	....	....	....	1	....	....	....	Snow and sleet.
Jan. 24	....	....	....	....	....	....	....	....	1	....	....	....	Sleet.
Jan. 28	....	....	....	....	....	....	—	....	1	....	....	....	Snow.
Feb. 1	....	....	....	....	....	1	1	....	1	....	....	....	Lt. snow.
Feb. 4	....	1	1	1	1	1	1	....	1	1	1	....	Lt. rain.
Feb. 5	....	....	....	....	....	....	—	....	1	....	....	....	Do.
Feb. 5	....	....	....	....	1	1	1	....	1	....	....	....	Lt. snow, moist.
Feb. 6	....	....	....	....	....	....	....	....	1	1	....	....	Lt. snow.
Feb. 9	....	....	....	....	....	....	....	....	....	....	....	....	Lt. and hy. rain; thunder.
Feb. 10	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain and lt. snow.
Feb. 13	....	....	....	....	....	....	1	....	1	....	....	....	Hy. snow.
Feb. 14	....	....	....	....	....	....	....	....	1	....	....	....	Lt. snow.
Feb. 15	....	....	....	....	....	....	....	....	....	....	....	....	Do.
Feb. 16	....	....	....	....	....	....	1	....	1	....	....	....	Hy. rain; lt. snow.
Feb. 17	....	....	....	....	....	....	....	....	1	....	....	....	Hy. snow.
Feb. 18	....	....	....	....	....	....	....	....	1	1	....	....	Lt. snow.
Feb. 24	....	....	....	....	....	....	....	....	1	....	....	....	Hy. snow.
Feb. 25	....	....	....	....	....	....	....	....	1	....	....	....	Hy. snow, 7.5 inches.
Feb. 26	....	1	....	....	....	....	....	....	1	....	....	....	Lt. sleet and snow.
Feb. 27	....	....	....	....	....	....	....	....	1	....	....	....	Lt. snow.
Mar. 1	....	....	....	1	1	....	1	....	1	1	1	....	Lt. rain.
Mar. 2	....	....	....	....	....	....	....	....	....	....	....	....	Do.
Mar. 7	....	....	1	1	1	....	1	....	1	....	....	....	Lt. snow.
Mar. 8	....	....	....	....	1	1	1	....	1	....	....	....	Do.
Mar. 12	....	....	....	....	....	1	1	....	1	....	....	....	Lt. rain and snow.
Mar. 13	....	....	....	....	....	....	....	....	1	....	....	....	Lt. snow.
Mar. 14	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Mar. 15	....	....	....	....	....	....	—	....	1	....	....	....	Lt. rain.
Mar. 15	....	....	....	....	1	1	1	....	1	1	1	1	Lt. rain; lt. fog.
Mar. 19	....	....	....	....	....	....	....	....	1	....	....	....	Lt. snow.
Mar. 22	....	....	....	1	1	1	1	....	1	1	1	1	Do.
Mar. 31	....	....	....	1	1	1	1	....	1	1	1	....	Lt. rain.
Apr. 3	....	....	....	....	....	....	1	....	1	....	....	....	Do.
Apr. 4	....	....	....	....	....	....	....	....	1	1	....	....	Do.
Apr. 4	....	....	....	....	1	1	1	....	1	1	1	1	Lt. sleet.
Apr. 5	....	....	....	....	....	....	1	....	1	1	....	....	Lt. rain.
Apr. 7	....	....	....	....	....	1	1	....	1	....	....	....	Do.
Apr. 8	....	1	1	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
Apr. 11	....	....	....	....	....	....	....	....	1	1	1	....	Lt. rain and snow.
Apr. 13	1	....	....	....	....	....	....	1	....	1	1	1	Lt. rain.
Apr. 15	....	....	....	....	....	1	1	....	1	1	....	....	Do.
Apr. 15	....	....	....	....	....	1	1	....	1	....	....	....	Do.
Apr. 16	....	....	....	....	....	....	....	....	1	1	....	....	Do.
Apr. 28	....	....	....	....	1	1	1	....	1	1	....	....	Do.
May 1	....	....	1	1	1	1	1	....	1	....	....	....	Do.
May 6	....	1	....	....	....	1	....	....	....	....	....	....	Do.
May 7	....	....	....	....	....	....	....	....	1	....	....	....	Hy. rain.
May 13	....	....	....	....	....	....	—	....	1	1	1	1	Lt. rain.
May 14	....	....	....	1	1	1	1	....	1	1	1	1	Do.
May 14	....	....	....	....	1	1	1	....	1	1	....	....	Do.
May 17	....	....	....	....	....	....	....	....	....	....	....	....	Trace of rain.
May 20	....	1	....	....	1	1	1	....	1	1	....	....	Lt. rain.
May 21	....	....	....	....	....	1	1	....	1	1	....	....	Do.
May 22	....	....	....	....	....	1	1	....	1	....	....	....	Hy. rain.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Before.							During.		After.			Remarks.
		Negative.											
	No record.	10 hours.	6–10 hours.	4–6 hours.	2–4 hours.	1–2 hours.	0–1 hour.	No record.	Negative.	0–1 hour.	1–3 hours.	3 + hours.	
1885.													
May 23	....	....	....	....	1	1	1	....	1	1	1	1	Lt. rain.
May 24	....	....	....	....	....	1	1	....	1	....	....	....	Do.
May 24	....	....	....	1	1	1	1	....	1	1	1	1	Do.
May 25	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
May 26	....	....	....	....	....	....	....	....	....	....	....	....	Do.
May 27	....	....	....	....	....	....	1	....	1	....	....	....	Lt. rain.
May 28	....	....	....	....	....	....	....	....	1	....	....	....	Do.
May 29	....	....	....	....	....	....	....	....	1	1	1	....	Do.
May 30	....	....	....	....	....	1	1	....	1	1	1	1	Do.
May 31	....	....	....	....	1	1	1	....	1	....	....	....	Rain and thunder.
May 31	....	....	....	....	....	....	....	....	....	....	....	....	Do.
June 4	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
June 5	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain, hail, and thunder; gale.
June 7	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; lightning.
June 8	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
June 15	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain and thunder.
June 16	....	....	....	....	....	....	....	....	....	....	....	....	Do
June 17	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain.
June 25	....	....	....	....	1	1	1	....	1	1	....	....	Lt. rain.
June 26	....	....	....	1	1	1	1	....	1	....	....	....	Do.
June 27	....	....	....	....	....	....	....	....	....	....	....	....	Do.
June 27	....	....	....	....	....	....	....	....	....	....	....	....	Do.
June 28	....	....	....	....	....	....	....	....	....	1	1	1	Hy. rain; thunder; 4.47 inches.
July 2	....	....	....	....	....	....	1	....	1	1	....	....	Lt. rain.
July 5	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder.
July 6	....	....	....	....	....	....	....	....	....	....	1	1	Lt. rain.
July 7	....	....	....	....	1	1	1	....	1	1	....	....	Do.
July 7	....	1	1	....	....	....	....	....	....	....	....	....	Trace of rain.
July 10	....	....	....	....	....	....	....	....	....	....	....	1	Do.
July 13	....	....	....	....	....	....	....	....	....	....	....	....	Do.
July 14	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
July 18	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
July 24	....	....	....	1	....	....	....	....	....	....	....	....	Lt. rain.
July 25	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain and lightning.
July 26	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder.
July 27	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
July 27	....	....	....	....	....	....	....	....	....	....	....	....	Trace of rain.
July 28	....	....	....	....	....	....	1	....	1	1	1	1	Lt. rain.
July 29	....	....	....	1	....	....	1	....	1	1	....	....	Do.
July 31	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
Aug. 1	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
Aug. 1	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain and thunder.
Aug. 2	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
Aug. 2	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; hy. thunder.
Aug. 3	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder; 3.35 inches.
Aug. 4	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
Aug. 7	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Aug. 8	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Aug. 12	....	....	....	....	....	....	....	....	....	....	....	....	Trace of rain.
Aug. 12	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
Aug. 13	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
Aug. 13	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
Aug. 14	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
Aug. 21	....	1	....	....	....	....	....	....	....	....	....	....	Do.
Aug. 22	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain and thunder.
Aug. 23	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
Aug. 23	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain and thunder.
Aug. 25	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain and thunder.
Aug. 26	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
Aug. 29	....	....	1	....	....	....	....	....	1	....	....	....	Do.
Aug. 30	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
Aug. 31	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
Sept. 4	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
Sept. 5	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Before.							During.		After.			Remarks.
		Negative.											
	No record.	10 hours.	6–10 hours.	4–6 hours.	2–4 hours.	1–2 hours.	0–1 hour.	No record.	Negative.	0–1 hour.	1–3 hours.	3 + hours.	
1885													
Sept. 5	....	....	....	....	....	....	....	....	1	1	1	....	Lt. rain.
Sept. 8	....	1	1	....	....	....	....	....	....	....	....	....	Do.
Sept. 9	....	....	....	....	....	....	—	....	1	....	....	....	Do.
Sept. 9	....	....	....	....	....	....	....	....	1	1	....	....	Do.
Sept. 10	....	....	....	1	....	....	....	....	1	1	1	....	Do.
Sept. 11	....	....	....	....	....	1	1	....	1	....	....	....	Do.
Sept. 22	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Sept. 23	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Oct. 2	....	....	....	....	....	....	....	....	1	1	1	1	Do.
Oct. 2	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
Oct. 3	....	....	....	....	....	....	....	....	....	....	....	....	Do.
Oct. 3	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Oct. 4	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; record not good.
Oct. 6	....	....	....	....	....	....	—	....	1	1	....	....	Lt. rain.
Oct. 8	....	....	....	....	....	....	1	....	1	1	....	....	Do.
Oct. 12	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Oct. 13	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Oct. 14	....	....	....	....	....	....	....	....	1	1	....	....	Do.
Oct. 21	....	....	....	....	....	....	—	....	1	....	....	....	Hy. rain.
Oct. 23	....	....	....	....	....	....	....	....	....	....	....	....	Trace of rain.
Oct. 29	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Oct. 29	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder.
Oct. 30	....	....	....	....	....	....	....	....	....	....	....	....	Do.
Oct. 30	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Nov. 1	....	....	....	....	....	1	1	....	1	....	....	....	Lt. rain and hy. rain.
Nov. 2	....	....	....	....	....	....	....	....	1	....	....	....	Hy. rain.
Nov. 5	....	....	....	....	....	....	....	....	....	1	1	....	Lt. rain.
Nov. 6	....	....	....	....	....	....	....	....	....	....	....	....	Trace of rain.
Nov. 7	....	....	....	....	....	....	1	....	1	1	....	....	Lt. rain.
Nov. 8	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Nov. 9	....	....	....	....	....	....	....	....	1	1	....	....	Do.
Nov. 13	....	....	....	....	1	....	....	....	1	....	....	....	Do.
Nov. 18	....	1	....	....	....	....	....	....	....	....	....	....	Trace of rain.
Nov. 19	....	....	....	....	....	....	....	....	1	1	1	....	Lt. rain.
Nov. 21	....	1	....	....	1	....	....	....	....	....	....	....	Do.
Nov. 22	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Nov. 23	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain and snow.
Nov. 24	....	....	....	....	....	....	....	....	1	1	....	....	Lt. rain.
Nov. 25	....	....	....	....	....	....	....	....	....	....	....	....	Trace of snow.
Nov. 27	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Nov. 28	....	....	....	....	....	....	....	....	....	1	1	....	Do.
Nov. 29	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Dec. 1	....	....	....	....	....	....	—	....	1	....	....	....	Do.
Dec. 3	....	....	....	....	1	1	1	....	....	....	1	....	Lt. rain and sleet.
Dec. 5	....	....	....	....	....	....	1	....	1	....	....	....	Lt. rain.
Dec. 9	....	....	....	....	....	1	1	....	....	....	....	....	Do.
Dec. 9	....	....	....	....	....	....	....	....	1	1	....	....	Hy. rain.
Dec. 9	....	....	....	....	....	....	....	....	....	1	....	....	Lt. rain.
Dec. 13	1	....	....	....	....	....	....	....	1	....	....	....	Do.
Dec. 14	....	....	....	....	....	....	....	....	1	....	....	....	Hy. rain.
Dec. 23	....	....	....	....	1	1	1	....	1	1	1	1	Lt. rain.
Dec. 31	....	....	....	....	....	....	—	....	1	....	....	....	Do.
1886.													
Jan. 4	....	....	....	....	....	....	....	....	1	1	1	1	Lt. to hy. rain.
Jan. 5	....	....	....	....	....	....	....	....	....	....	....	....	Trace of snow.
Jan. 6	....	....	....	....	....	....	....	....	....	....	....	....	Do.
Jan. 8	....	....	....	....	....	....	1	....	1	....	....	....	Lt. and hy. snow.
Jan. 9	....	....	....	....	....	....	....	....	1	....	....	....	Hy. snow.
Jan. 25	1	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Jan. 27	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Jan. 28	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Jan. 29	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Jan. 30	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain and snow.
Feb. 3	....	....	....	....	....	....	—	....	1	....	....	....	Hy. snow.
Feb. 4	....	....	....	....	....	....	....	....	1	....	....	....	Hy. snow, 15 inches.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Before.							During.		After.			Remarks.
		Negative.											
	No record.	10 hours.	6-10 hours.	4-6 hours.	2-4 hours.	1-2 hours.	0-1 hour.	No record.	Negative.	0-1 hour.	1-3 hours.	3+ hours.	
1886.													
Feb. 10	....	....	....	....	....	1	....	....	....	....	....	....	Lt. rain.
Feb. 11	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Feb. 12	....	....	....	....	....	....	....	1	....	....	....	....	Do.
Feb. 13	....	....	....	....	....	....	....	1	....	....	....	....	Do.
Feb. 15	....	....	1	....	....	....	....	....	1	1	....	....	Do.
Feb. 23	....	1	....	....	1	1	1	....	1	1	....	....	Do.
Feb. 25	....	....	....	....	....	....	—	....	1	....	....	....	Hy. rain.
Feb. 26	....	....	....	....	1	1	1	....	....	....	....	1	Lt. snow.
Mar. 8	....	....	....	....	....	....	—	....	1	1	1	1	Do.
Mar. 12	....	....	....	....	....	....	1	....	1	1	1	....	Lt. rain and sleet.
Mar. 13	....	....	....	....	....	....	1	....	1	1	....	....	Lt. rain.
Mar. 18	....	1	1	1	1	1	1	....	1	1	1	....	Do.
Mar. 19	....	....	....	....	1	1	1	....	1	1	....	....	Do.
Mar. 20	....	1	1	....	....	....	1	....	1	....	....	....	Do.
Mar. 21	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Mar. 21	....	....	....	....	....	....	....	....	1	1	....	....	Do.
Mar. 22	....	1	....	....	....	....	....	....	....	....	....	1	Do.
Mar. 26	....	1	1	1	1	1	1	....	1	....	....	....	Do.
Mar. 27	....	....	....	....	....	....	....	....	1	1	1	....	Do.
Mar. 28	....	....	....	....	....	....	—	....	1	....	....	....	Do.
Mar. 29	....	....	....	....	....	....	1	....	1	....	....	....	Do.
Mar. 30	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Mar. 31	....	....	....	....	....	....	....	....	1	1	1	1	Do.
Apr. 3	....	1	1	1	1	1	1	....	1	1	1	1	Do.
Apr. 4	....	1	1	1	1	1	1	....	1	....	....	....	Do.
Apr. 5	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Apr. 6	....	....	....	....	....	....	....	....	1	1	1	1	Do.
Apr. 7	....	....	....	1	....	....	....	....	....	....	....	....	Do.
Apr. 7	....	....	....	....	....	....	1	....	1	....	....	....	Do.
Apr. 11	....	....	....	1	1	1	1	....	1	....	....	....	Do.
Apr. 12	....	1	....	....	....	....	....	1	....	....	....	....	Do.
Apr. 13	....	....	....	1	1	....	....	....	1	....	....	....	Do.
Apr. 13	....	....	....	....	....	....	1	....	1	....	....	....	Lt. rain; thunder.
Apr. 16	....	....	....	....	....	1	....	....	....	....	....	....	Lt. rain.
Apr. 17	....	....	....	1	....	....	—	....	1	....	....	....	Do.
Apr. 24	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
Apr. 25	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
Apr. 25	....	....	....	....	....	....	1	....	1	1	1	1	Do
June 30	....	....	....	....	....	1	1	....	1	1	1	....	Do.
July 1	....	1	....	....	1	....	....	....	....	....	....	....	Do.
July 2	....	....	....	....	....	....	....	....	1	....	....	....	Hy. rain.
July 10	....	1	....	....	....	1	1	....	1	....	....	....	Lt. rain.
July 13	....	....	....	1	1	....	1	....	1	....	....	....	Do.
July 14	....	....	....	....	....	....	....	....	....	....	....	....	Do.
July 14	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder.
July 15	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain 2.09 in.; thunder; tornado.
July 16	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
July 18	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
July 21	....	....	1	....	....	....	1	....	1	1	1	1	Hy. rain.
July 25	....	....	....	....	....	1	1	....	1	....	....	....	Lt. rain.
July 26	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder.
July 27	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
July 31	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain and thunder.
Aug. 1	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
Aug. 2	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; lightning.
Aug. 7	....	....	....	....	....	....	....	....	....	....	....	....	Trace of rain.
Aug. 17	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
Aug. 17	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
Sept. 15	1	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Sept. 16	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Sept. 19	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder.
Sept. 19	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
Sept. 21	....	....	....	....	....	....	....	1	....	....	....	....	Lt. rain.
Sept. 22	....	....	....	....	....	....	....	1	....	....	....	....	Do.
Sept. 22	....	....	....	....	....	1	1	....	1	....	....	....	Do.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Before.							During.		After.			Remarks.
		Negative.											
	No record.	10 hours.	6-10 hours.	4-6 hours.	2-4 hours.	1-2 hours.	0-1 hour.	No record.	Negative.	0-1 hour.	1-3 hours.	3 + hours.	
1886.													
Sept. 29	....	....	....	....	....	1	1	....	1	....	....	....	Hy. rain.
Oct. 14	....	....	....	....	1	1	1	....	1	1	1	1	Lt. rain.
Oct. 14	....	....	....	1	1	1	1	....	1	1	....	....	Do.
Oct. 21	....	....	....	....	....	....	1	....	1	....	....	....	Do.
Oct. 26	....	....	1	1	1	1	1	....	1	....	....	....	Do.
Oct. 27	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Oct. 28	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Oct. 29	....	....	....	....	....	....	....	....	....	....	....	....	Trace of rain.
Oct. 30	....	....	....	1	1	1	1	....	1	....	....	....	Lt. rain.
Oct. 31	....	....	....	....	....	1	1	....	1	....	....	....	Do.
Nov. 6	....	....	....	....	....	....	1	....	1	....	....	....	Do.
Nov. 6	....	....	1	....	....	....	....	....	1	....	....	....	Do.
Nov. 7	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Nov. 10	....	....	....	....	....	....	—	....	1	....	....	....	Do.
Nov. 12	....	....	....	....	....	....	1	....	1	1	1	....	Hy. rain.
Nov. 13	....	....	....	....	....	....	....	....	....	....	....	....	Lt. snow; high positive during.
Nov. 17	....	1	1	1	1	1	1	....	1	....	....	....	Lt. rain.
Nov. 18	....	....	....	....	....	....	1	....	1	....	....	....	Hy. rain.
Nov. 22	....	....	....	....	1	1	1	....	1	....	....	....	Lt. rain.
Nov. 23	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Nov. 23	....	....	....	....	....	....	1	....	1	....	....	....	Do.
Nov. 24	....	....	....	....	....	....	—	....	1	....	....	....	Do.
Nov. 25	....	....	....	....	....	....	—	....	1	....	....	....	Lt. rain; hy. rain; waterspout.
Nov. 30	....	1	1	....	....	....	1	....	1	....	....	....	Lt. rain.
Dec. 4	1	....	....	....	....	....	....	....	1	....	....	....	Lt. snow.
Dec. 5	....	....	....	....	....	....	....	....	1	1	1	1	Do.
Dec. 6	....	1	....	....	....	....	....	....	1	....	....	....	Do.
Dec. 6	....	....	....	....	1	1	1	....	1	....	....	....	Lt. rain and snow.
Dec. 7	....	....	....	....	....	....	....	....	1	....	....	....	Lt. snow.
Dec. 12	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Dec. 13	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Dec. 15	1	....	....	....	....	....	....	....	1	....	....	....	Lt. rain and snow.
Dec. 16	....	....	....	....	....	....	....	....	1	1	1	1	Lt. snow.
Dec. 18	....	....	....	....	1	1	1	....	1	....	....	....	Hy. rain.
Dec. 22	....	....	....	1	1	1	1	....	1	....	....	....	Lt. rain.
Dec. 23	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Dec. 24	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Dec. 26	....	....	....	....	....	1	1	....	1	....	....	....	Lt. and hy. snow.
Dec. 29	....	....	....	....	....	1	1	....	1	....	....	....	Lt. snow.
Dec. 30	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Dec. 31	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
1887.													
Jan. 1	....	....	....	....	....	....	....	....	I	....	....	....	Lt. rain.
Jan. 1	....	....	....	1	1	1	....	....	....	....	....	....	Lt. snow; trace.
Jan. 9	....	....	....	....	....	....	....	....	....	....	....	....	Lt. snow and sleet.
Jan. 10	....	....	....	....	....	....	....	....	....	....	....	....	Lt. snow.
Jan. 13	....	1	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Jan. 14	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Jan. 17	....	....	....	....	1	1	1	....	1	1	....	....	Do.
Jan. 24	....	....	....	....	....	....	—	....	1	....	....	....	Lt. rain and snow.
Jan. 26	....	....	....	....	....	....	1	....	1	....	....	....	Lt. rain.
Jan. 26	....	1	1	....	....	....	....	....	....	....	....	....	Lt. snow.
Jan. 29	....	....	....	....	....	....	1	....	1	....	....	....	Lt. rain.
Feb. 2	....	....	....	....	....	1	1	....	1	....	....	....	Snow, sleet, and rain.
Feb. 3	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Feb. 3	....	1	....	....	....	....	....	....	1	1	....	....	Do.
Feb. 5	....	....	....	....	....	....	....	....	1	....	....	....	Snow, rain, and sleet.
Feb. 5	....	....	1	1	....	....	....	....	....	....	....	....	Lt. rain.
Feb. 6	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Feb. 7	....	....	....	....	....	....	....	1	....	....	....	....	Do.
Feb. 7	....	....	....	1	....	....	....	....	....	....	....	....	Do.
Feb. 8	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Feb. 10	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Feb. 11	....	....	1	1	....	....	....	1	....	....	....	....	Lt. rain; gale.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Before.							During.		After.			Remarks.
		Negative.											
	No record.	10 hours.	6–10 hours.	4–6 hours.	2–4 hours.	1–2 hours.	0–1 hour.	No record.	Negative.	0–1 hour.	1–3 hours.	3 + hours.	
1887.													
Feb. 14	....	....	....	....	....	....	....	....	1	....	....	....	Lt. snow and rain.
Feb. 15	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Feb. 18	....	....	1	....	....	1	1	....	1	....	....	....	Do.
Feb. 18	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; hail; thunder.
Feb. 20	....	....	....	....	....	....	1	....	1	....	....	....	Lt. rain; snow.
Feb. 21	....	....	....	....	....	....	....	....	1	....	....	....	Snow, sleet, and rain.
Feb. 23	....	....	....	....	....	1	1	....	1	....	....	....	Lt. snow and rain.
Feb. 24	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Feb. 26	....	....	....	....	....	....	....	....	1	1	....	....	Hy. snow; lt. rain.
Feb. 27	....	....	....	....	....	....	....	....	....	....	....	....	Trace of snow; high positive during.
Mar. 3	....	....	1	1	1	1	1	....	1	....	....	....	Lt. rain and sleet.
Mar. 3	....	....	....	....	1	1	1	....	1	....	....	....	Sleet and rain.
Mar. 4	....	....	....	....	....	....	....	1	....	....	....	....	Rain and snow.
Mar. 5	....	1	....	....	....	....	....	....	1	....	....	....	Snow, sleet, and rain.
Mar. 6	....	....	....	....	....	....	....	....	1	....	....	1	Lt. rain.
Mar. 7	....	....	....	....	....	....	—	....	1	....	....	....	Hy. rain.
Mar. 9	....	1	....	....	....	1	1	....	1	....	....	....	Do.
Mar. 10	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain.
Mar. 13	....	....	....	....	....	1	1	....	1	....	....	....	Hy. rain.
Mar. 14	....	....	....	....	....	....	....	....	1	1	1	....	Lt. rain.
Mar. 17	....	....	....	....	1	1	....	....	1	....	....	....	Lt. snow.
Mar. 18	....	....	....	....	....	....	....	....	1	1	1	1	Do.
Mar. 21	....	....	....	....	....	....	....	....	1	....	....	....	Lt. rain and snow.
Mar. 22	....	....	....	....	....	....	....	....	1	....	....	....	Snow and rain.
Mar. 24	....	1	....	....	....	....	1	....	1	1	....	....	Lt. rain.
Mar. 27	....	1	....	1	1	1	1	....	1	....	....	....	Hy. rain.
Mar. 28	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Mar. 28	....	....	....	....	....	....	1	....	1	1	....	....	Lt. snow.
Mar. 31	....	....	1	1	1	1	1	....	1	....	....	....	Do.
Apr. 1	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Apr. 2	....	....	....	....	....	....	....	....	....	....	....	....	Do.
Apr. 4	....	1	1	1	1	1	1	....	1	1	....	....	Lt. rain.
Apr. 5	....	....	1	1	1	1	1	....	1	....	....	....	Lt. snow.
Apr. 15	....	....	....	....	1	1	1	....	1	1	1	1	Lt. rain; thunder.
Apr. 16	....	....	....	....	1	1	1	....	1	....	....	....	Lt. rain.
Apr. 17	....	....	....	....	....	....	....	....	1	1	....	....	Do.
Apr. 18	....	....	....	....	....	....	1	....	1	....	....	....	Do.
Apr. 19	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Apr. 22	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Apr. 23	....	....	....	....	....	....	....	....	1	1	1	....	Do.
Apr. 25	....	....	....	....	....	....	1	....	1	....	....	....	Hy. rain.
Apr. 26	....	....	....	....	....	....	....	....	1	....	....	....	Do.
Apr. 26	....	....	....	....	....	1	1	....	1	....	....	....	Lt. rain.
Apr. 27	....	....	....	....	....	....	1	....	1	....	....	....	Do.
Apr. 27	....	....	....	....	....	....	1	....	1	....	....	....	Do.
Apr. 28	....	....	....	....	1	1	1	....	1	....	....	....	Do.
Apr. 28	....	1	....	....	....	....	....	....	1	....	....	....	Do.
Apr. 29	....	....	....	....	....	1	1	....	1	....	....	....	Do.
May 1	....	....	....	....	....	....	....	....	....	....	....	....	Trace of rain.
May 5	....	....	1	1	1	1	1	....	1	....	....	....	Lt. rain; sheet lightning.
May 6	....	1	1	1	1	1	1	....	1	....	....	....	Lt. rain; thunder.
May 7	....	....	....	....	....	....	....	....	....	....	....	....	Do.
May 8	....	....	....	....	....	....	....	....	....	....	....	....	Do.
May 9	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
May 10	....	....	....	....	1	1	1	....	1	1	1	....	Do.
May 24	....	....	....	....	....	....	1	....	1	....	....	....	Do.
May 25	....	....	....	....	....	....	....	....	....	....	....	....	Do.
May 25	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder.
May 26	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
May 26	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder.
May 27	....	....	....	....	....	....	1	....	1	....	....	....	Lt. rain.
May 28	....	1	1	1	....	....	....	1	....	....	....	....	Do.
May 31	....	....	1	1	....	....	1	....	1	....	....	....	Hy. rain.
June 1	....	....	....	....	....	....	....	....	1	....	....	....	Do.
June 2	....	....	....	....	....	....	1	....	1	....	....	....	Lt. rain.

TABLE P.—*Potential on days on which precipitation occurred at Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Before.							During.		After.			Remarks.
		Negative.											
	No record.	10 hours.	6–10 hours.	4–6 hours.	2–4 hours.	1–2 hours.	0–1 hour.	No record.	Negative.	0–1 hour.	1–3 hours.	3 + hours.	
1887.													
June 2	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder.
June 3	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
June 6	....	....	....	....	....	1	....	....	1	....	....	....	Do.
June 7	....	....	....	....	....	....	1	....	1	....	....	....	Hy. rain.
June 7	....	....	....	....	1	1	1	....	1	1	....	....	Lt. rain.
June 9	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain and thunder.
June 18	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; hail and thunder.
June 19	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
June 19	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder.
June 20	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
June 20	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain and thunder.
June 21	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain; thunder.
June 22	....	....	....	....	....	....	....	....	....	....	....	....	Do.
June 22	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder.
June 23	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
June 23	....	....	....	....	....	....	....	....	....	....	....	....	Do.
July 5	....	....	....	....	....	....	....	....	....	....	....	....	Do.
July 5	....	....	....	....	....	1	1	....	1	1	1	1	Hy. rain.
July 5	....	....	....	....	1	1	1	....	1	1	....	....	Lt. rain.
July 5	....	....	....	....	....	....	1	....	1	1	....	....	Thunderstorm.
July 6	....	....	....	....	....	....	....	....	....	....	....	1	Lt. rain.
July 9	....	1	....	....	....	....	....	....	1	1	....	....	Lt. rain; thunder.
July 17	....	....	....	....	....	....	....	....	....	....	....	....	Do.
July 18	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; hail and thunder.
July 19	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain and thunder.
July 19	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
July 20	....	....	....	1	1	....	....	....	....	1	1	1	Do.
July 21	....	....	....	....	....	....	....	....	....	....	....	....	Do.
July 21	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder 2.70 inches.
July 23	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder 1.11 inches.
July 23	....	....	....	....	....	....	....	....	....	....	....	....	Lt. rain.
July 24	....	....	....	....	....	....	....	....	....	....	....	....	Do.
July 24	....	....	....	....	....	....	....	....	....	....	....	....	Do.
July 24	....	....	....	....	....	....	1	....	1	....	....	....	Do.
July 25	....	....	....	....	....	....	....	....	....	....	....	....	Trace of rain.
July 26	....	....	....	....	....	....	....	....	....	....	....	....	Hy. rain; thunder 1.55 inches.
July 27	....	....	....	....	....	....	1	....	1	....	....	....	Lt. rain.
July 29	....	....	....	....	....	....	....	....	....	....	....	....	Trace of rain.
July 29	....	....	....	....	....	....	....	....	....	....	....	....	Lightning.
Aug. 2	....	....	....	....	....	....	....	....	....	....	....	....	Trace of rain.

TABLE Q.—*Potential on days on which precipitation occurred at Washington, D. C., October* 1, 1887, *to August* 31, 1888.

Date.	Remarks.
1887.	
Oct. 18	Lt. rain, b. d n., e. 7:50 a. m., b. 4:10 p. m., e. 5:05 p. m., b. 6:06 p. m., e. 9:15 p. m.; no special observations; positive at all regular observations.
Oct. 20	Lt. rain, b. 7:45 a. m., e. 9:50 p. m., 1.14 inches; variable positive and negative all day, 9 a. m. to 5 p. m.
Oct. 24	A trace of rain from 4:30 to 4:35 a. m., from 2 to 2:30 p. m., and from 6:35 to 8:45 p. m.; no special observations; positive at all regular observations.
Oct. 25	Sleet, b. 8:45 a. m., changed to rain 9:25 a. m., e. 4:50 p. m.; lt. rain, b. 6 p. m., e. 8:30 p. m., 0.22 inch; variable positive and negative all day.
Oct. 26	Lt. rain from 10:10 to 11:25 a. m. and from 1:30 to 8:30 p. m., 0.02 inch; no special observations; positive at all regular observations.
Oct. 27	Lt. drizzling rain all day; no negative observed.
Oct. 28	Do.
Nov. 10	Lt. rain from 8:30 a. m. to 2 p. m., 0.30 inch; variable positive and negative from 9 a. m. to 1:30 p. m.

TABLE Q.—*Potential on days on which precipitation occurred at Washington, D. C., October* 1, 1887, *to August* 31, 1888—Continued.

Date.	Remarks.
1887.	
Nov. 11	A trace of snow from 2:15 to 2:30 p. m.; no observations between 1 and 3 p. m.; positive at those hours.
Nov. 14	Positive from 9 a. m. to 3 p. m.; no observations from 3 to 5 p. m.; positive at 5 p. m.; no observations after this; lt. rain from 4:40 to 4:45 p. m. and from 5:35 to 11:55 p. m., 0.10 inch.
Nov. 19	Lt. rain, b. 8:50 a. m., e. 2:45 p. m.; variable positive and negative from 9 a. m. to 1:45 p. m.
Nov. 28	Lt. rain from 8 a. m. to 1:35 p. m.; variable positive and negative from 9:30 a. m. to 1:35 p. m.
Dec. 2	A trace of snow from 8:10 to 9:05 a. m.; positive at 9 a. m.; no other observations.
Dec. 8	Lt. rain from 7:47 to 9:20 a. m. and from 10:55 a. m. to 12:10 p. m., 0.01 inch; no special observations; positive at all regular observations.
Dec. 10	Lt. rain, b. d. n., e. 9:55 a. m.; negative from 9 to 9:30 a. m.; lt. rain from 12:05 to 2:45 p. m., from 3:14 to 5:20 p. m., and from 9:50 to 10:35 p.m.; variable positive and negative from 1:30 to 5 p. m.; amount of rain, 0.89 inch.
Dec. 15	Hy. rain from 3:25 a. m. to 2:48 p. m., 0.92 inch; variable positive and negative from 9 a. m. to 12:35 p. m.
Dec. 17	Threatening at 9 a. m.; hy. snow from 1 to 9:10 p. m., 0.64 inch of melted snow; variable positive and negative from 10 a. m. to the last observation, at 5:20 p. m.
Dec. 20	Lt. rain, b. 9 a. m., changed to sleet at 10:20 a. m., e. 9:50 p. m., 0.57 inch; variable positive and negative from 9:50 a. m. to the last observation, at 5:15 p. m.
Dec. 26	A trace of snow from 3:48 to 7 p. m.; no observation after 1 p. m., except at 5 p. m., when it was positive.
Dec. 28	Hy. rain from 3:40 a. m. to 1 p. m., 0.63 inch; variable positive and negative from 9 a. m. to 12:30 p. m.
Dec. 31	Threatening at 9 a. m.; negative at 1 p. m.; positive at the other regular observations; no special observations; hy. snow, b. 12:40 p. m., changed to sleet 5:45 p. m., e. 7 p. m., 0.42 inch.
1888.	
Jan. 1	Hy. rain, b. d. n., e. 2:30 p. m., 0.85 inch; negative at 9 and 11 a. m. and 1 p. m.; positive at 3 and 5 p. m.; no special observations.
Jan. 6	Variable positive and negative from 9 to 10 a. m., with threatening weather; a trace of rain from 11:20 to 11:45 a. m., from 4:40 to 4:45 p. m., and from 5:15 to 5:45 p. m.; negative and positive during first rain; no observations during others.
Jan. 9	Lt. snow and rain from 10:55 a. m. to d. n., 0.31 inch; positive at 9 a. m.; no observations between 9 and 11 a. m.; variable positive and negative at 11 a. m. and 1 and 3 p. m.; positive at 5 p. m.
Jan. 13	Rain and sleet, b. d. n., e. 12:45 p.m., 0.70 inch; generally negative at 9 and 11 a. m. and 1 p. m.; no observations at 3 p. m.; positive at 5 p. m.
Jan. 17	Lt. snow and sleet, b. 2:45 a. m., e. 5:30 p. m., 0.26 inch; variable positive and negative all day, 9 a. m. to 5 p. m.
Jan. 23	A trace of snow from 1:35 to 1:45 p. m.; positive at 9 and 11 a. m. and 1 p. m.; variable positive and negative at 3 p. m.
Jan. 25	Hy. snow from 1:35 to 8:10 p. m., 0.60 inch; positive at 9 and 11 a. m. and 1 p. m.; no observations from 1 to 3 p. m.; variable positive and negative at 3 and 5 p. m.
Jan. 29	Negative at 4:55 p. m.; high positive 5:10 to 5:20 p. m.; no observations after this; lt. snow from 6 to 8:35 p. m., 0.03 inch.
Jan. 31	Lt. rain from 3:30 to 7:10 a. m., 0.15 inch; a trace of rain from 1:55 to 2:10 p. m.; no special observations during the day; positive at all regular observations.
Feb. 4	Lt. rain from 1:40 a. m. to 9:10 p. m., 0:48 inch; negative at 9 a. m.; positive at 11 a. m., and 1, 3, and 5 p. m.; no special observations.
Feb. 7	Lt. rain mist, from 6:20 a. m. to 12:10 p. m., 0.03 inch; positive from 9 a. m. to 5 p. m.
Feb. 8	Lt. rain, b. 8:20 a. m., e. 12:15 p. m., 0.40 inch; variable positive and negative from 9 a. m. to 1 p. m.
Feb. 9	A trace of snow from 6:25 a. m. to 12:50 p. m.; positive all day.
Feb. 10	Lt. snow and sleet from 1:10 a. m. all day., 0.16 inch; high positive from 9 a. m. to 1 p. m. during snow; negative from 2 to 7 p. m., during snow and sleet.
Feb. 11	Sleet and rain, b. d. n., e. 4:40 p. m., 0.42 inch; variable positive and negative from 9 a. m. to 1 p. m.
Feb. 20	Lt. rain, b. 5:30, e. 7:30 a. m.; b. 11:40 a. m., e. 12:30 p. m.; b. 2:50, e. 3:10 p. m.; b. 5:05, e. 5:07 p. m.; 0:10 inch; no special observations; positive at all regular observations.
Feb. 27	Lt. snow from 6:25 to 11:30 a. m., 0.06 inch; variable positive and negative from 9 to 10 a. m.; positive rest of the time.
Mar. 1	A trace of rain from 1:15 to 2:25 p. m.; no special observations; positive at regular observations.
Mar. 2	A trace of rain 12:45 p. m.; no special observations; positive at the regular observations.
Mar. 5	Lt. and hy. snow from 6:15 a. m. to 9:40 p. m., 0.42 inch; variable positive and negative from 9 a. m. to 3 p. m.
Mar. 13	A trace of snow from 11:40 a. m. to 8:30 p. m.; positive all day.
Mar. 14	A trace of snow from 9 to 10 a. m.; positive all day.
Mar. 16	Threatening and negative at 4:58 p. m.; lt. rain from 5:45 to 7:20 p. m.; no observation after 5 p. m.
Mar. 20	Lt. rain from 5:30 a. m. to 2:15 p. m., 0.44 inch; negative from 9 to 11 a. m.; variable positive and negative from 11 a. m. to 12 m.
Mar. 21	Lt. rain from 3:45 to 7:50 a. m. and from 1:35 to 4:15 p. m., 0.50 inch; positive from 9 a. m. to 1 p. m.; no observations from 1 to 1:45 p. m.; variable positive and negative from 1:45 to 4 p. m.
Mar. 22	A trace of snow from 6:20 to 7:50 a. m., and from 2:55 to 3:30 p. m.; positive all day.

TABLE Q.—*Potential on days on which precipitation occurred at Washington, D. C., October* 1, 1887, *to August* 31, 1888—Continued.

Date.	Remarks.
1888.	
Mar. 24	A trace of snow from 4 to 11:15 a. m.; positive all day.
Mar. 26	Hy. rain began d. n., e. 11 a. m.; lt. rain from 2:40 p. m. to d. n., 0.69 inch; negative from 9 a. m. to 12 m.; variable positive and negative from 12 m. to 3 p. m.
Mar. 27	Negative at 3:15 p. m.; lt. rain b. 5:30 p. m., e. d. n.; no observations after 5 p. m.
Mar. 29	Lt rain from 8:50 to 10:20 a. m., 0.21 inch.; no special observations; positive at the regular observations.
Apr. 5	Lt. rain from 5:20 a. m. to 12:05 p. m., 0.28 inch; thunderstorm from 9:30 to 10:30 a. m.; variable positive and negative from 9 a. m. to 1 p. m.
Apr. 10	Lt. and hy. rain from 1:45 a. m. to 6:40 p. m., 0.77 inch.; variable positive and negative from 9 a. m. to 3 p. m., and all day on the 9th.
Apr. 12	A trace of rain from 12:28 to 12:32 p. m.; negative from 12:09 to 12:26 p. m.; positive rest of the time.
Apr. 14	Lt. rain early a. m. to 11:10 a. m.; potential variable ne ative all day.
Apr. 15	Negative at 5:38 p. m.; no observations after this; lt. rain from 8:15 to 11:20 p. m., 0.12 inch.
Apr. 16	Lt. rain from 7:40 to 9:20 a. m., 0.05 inch.; variable positive and negative from 9 to 9:10 a. m.
Apr. 19	Negative at 3 p. m.; no other observations until 5 p. m.; lt., rain from 3:25 to 3:35 p. m.
Apr. 23	Lt. rain b. d. n., e. 9:10 a. m., 0.34 inch; negative at 9 a. m.; no special observations.
May 1	Lt. rain from 7:10 to 10:35 a. m., 0.10 inch; variable positive and negative from 10 to 11 a. m.
May 4	Negative at 3 p. m.; no observations after 5 p. m.; lt. rain from 8:10 to 10:25 p. m.
May 8	Variable positive and negative from 10 a. m. to 12 m.; lt. rain from 10 p. m. to d. n.
May 10	Lt. rain from 8:40 to 10:45 p. m.; negative at 3 p. m.; no observation after 5 p. m.
May 11	Lt. rain b. 6 a. m., e. 11:05 a. m., b. 1:50 p. m., e. 4:30 p. m., 0.27 inch.; no special observations; negative at 3 p. m.; positive at the other observations.
May 12	Lt. rain from 3:45 to 9:10 p. m., 0.55 inch; low positive all day; high positive at 5 p. m.; no special observations.
May 14	Lt. rain from 9:40 to 11:35 a. m., and from 6:30 to 8 p. m., 0.14 inch; no special observations; positive at the regular observations.
May 18	Lt. rain from 3:45 to 11:50 a. m., and from 1:35 to 1:55 p. m., 0.37 inch; no special observations; negative at 9 and 11 a. m.
May 23	Lt. rain from 2:30 a. m. to 4:40 p. m., 0.74 inch; positive at the regular; no special observations.
May 24	Lt. rain b. d. n., e. 7:45 p. m., 0.68 inch; positive at the regular; no special observations.
May 25	Negative at 1 p. m.; lt. rain from 3:05 to 3:25 p. m.; no special observations.
May 26	Lt. rain 2:35 to 4:10 a. m.; lt. rain from 4:50 to 5:15 p. m.; negative at 9 a. m. and 5 p. m.; no special observations.
May 30	Lt. rain 8:40 to 9:25 a. m., and from 4:12 to 8:15 p. m., 0.12 inch; positive at 9 a. m. and 3 and 5 p. m.; no other observations.
May 31	Lt. rain 4:30 a. m. to 2 p. m., and from 5:30 to 8:30 p. m., 0.45 inch; negative at 11 a.m. and 1 p. m.
June 14	Negative from 4:28 to 4:40 p. m.; variable positive and negative from 4:40 to 5:05 p. m.; hy. rain from 4:40 to 5:07 p. m., 0.40 inch; thunderstorm from 4:34 to 5 p. m.
June 16	Lt. rain from 4:03 to 7:10 p. m., 0.22 inch; no special observations; positive at 3 and 5 p. m.
June 23	Negative at 1 and 3 p. m.; no special observations; lt. rain from 3:16 to 5:35 p. m., 0.69 inch.
June 26	Lt. rain in early a. m., and from 11:25 to 11:27 a. m.; positive from 9 a. m. to 5 p. m.; no observations from 11:25 to 11:30 a.m.
June 27	Lt. rain from 10:10 to 10:25 a. m., and from 2:05 to 8:10 p. m., 0.10 inch.; no special observations: negative at 1 p. m.; positive at the other observations.
June 28	Hy. rain b. d. n., e. 10:50 a. m.; lt. rain from 4:20 to 5:10 p. m., 1.34 inches; no special observations; positive at 9 and 11 a. m., and 1 and 3 p. m.; negative at 5. p. m.
June 29	Rained d. n., e. 9:12 a. m., b. 11:25 a. m., e. 12:40 p. m., 0.53 inch; negative at 9 a. m.; positive at other observations; no special observations.
July 5	No special observations; positive at 9 and 11 a. m., and 1 p. m.; negative at 3 and 5 p. m.; lt. rain 2:15 to 5:35 p. m., 0.02 inch.
July 9	Lt. rain from 8:35 a. m. to 1:15 p. m. and 3:15 to 3:20 p. m., 0.46 inch; positive at regular; no special observations.
July 10	Lt. rain b. d. n., e. 12 m.; negative at 9 and 11 a. m.; positive at 1, 3, and 5 p. m.
July 19	Lt. rain from 10:55 a. m. to 7:50 p. m., 0.06 inch; variable positive and negative at 11 a. m. and 3 p. m.; positive at 9 a. m., and 1 and 5 p. m.; no special observations.
July 30	Lt. rain from 12:05 to 3:10 p. m.; negative at 11 a. m.; variable positive and negative at 3 p. m.; no special observations.
Aug. 4	Light rain 8:40 to 8:50 p. m.; negative potential at 5 p. m.; no special observations.
Aug. 8	Hy. rain with thunder from 4:50 to 8:25 p. m., 0.79 inch; positive at 3 p. m.; negative at 5 p. m.; no special observations.
Aug. 17	Positive at 1 and 3 p. m.; negative at 5 p. m.; no special observations; lt. rain from 1:58 to 4:50 p. m., 0.03 inch; distant thunder at 5 p. m.
Aug. 18	Lt. rain from 7:10 to 9:47 a. m. and from 5:45 to 7:35 p. m., 0.17 inch; no special observations; negative at 11 a. m.; positive at other observations.
Aug. 21	Lt. rain 11:50 to 11:55 a. m.; 1:20 to 1:50 p. m.; 3:45 to 4:05 p. m., and 5:45 to 6:20 p. m., 0.89 inch; potential less than 10 volts all day; negative at 3 p. m.
Aug. 27	Lt. rain from 3:45 to 6:10 p. m., 0.17 inch; distant thunder at 4:45 p. m.; variable positive and negative from 4:45 to 5:30 p. m.; no observations from 3 to 4:45 p. m.; positive at 3 p. m.
Aug. 31	Lt. rain from 1:52 to 3:25 p. m., 0.08 inch; no special observations; positive at 1 and 5 p. m; variable positive and negative at 3 p. m.

TABLE Q.—*Potential on days on which precipitation occurred at Washington, D. C., October* 1, 1887, *to August* 31, 1888—Continued.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative observed.	No observation.	Negative.	No negative.		
1887.										
Oct. 18	4:10 p. m.	9:15 p. m.	....	....	1	....	....	1	....	No sp. obs. Lt. rain.
Oct. 20	7:45 a. m.	9:50 p. m.	1	....	....	....	1	....	....	Hy. rain, 1.14 inches.
Oct. 23	2 p. m.	8:45 p. m.	....	....	1	....	....	1	....	No sp. obs. Lt. rain.
Oct. 24	8:45 p. m.	8:30 p. m.	1	....	....	....	1	....	....	Sleet and rain, 0.22 inch.
Oct. 25	10:10 a. m.	8:30 p. m.	....	....	1	....	....	1	....	Lt. rain, 0.02 inch. No sp. obs.
Oct. 26	All day.		1	....	....	....	....	1	....	Lt. drizzling rain.
Oct. 27	All day.		1	....	....	....	....	1	....	Do.
Nov. 10	8:30 a. m.	2 p. m.	1	....	....	....	1	....	....	Lt. rain, 0.30 inch.
Nov. 11	2:15 p. m.	2:30 p. m.	....	....	1	1	....	....	....	Lt. snow, tr. No sp. obs.
Nov. 14	4:40 p. m.	11:55 p. m.	....	....	1	....	....	1	....	Lt. rain, 0.10 inch. No sp. obs.
Nov. 19	8:50 a. m.	2:45 p. m.	1	....	....	....	1	....	....	Lt. rain.
Nov. 28	8 a. m.	1:35 p. m.	1	....	....	....	1	....	....	Do.
Dec. 2	8:10 a. m.	9:05 a. m.	1	....	....	....	....	1	....	Lt. snow, tr.
Dec. 8	7:47 a. m.	12:10 p. m.	1	....	....	....	....	1	....	Lt. rain, 0.01 inch. No sp. obs.
Dec. 10	D. n.	10:35 p. m.	1	....	....	....	1	....	....	Lt. rain, 0.89 inch.
Dec. 15	3:25 a. m.	2:48 p. m.	1	....	....	....	1	....	....	Hy. rain, 0.92 inch.
Dec. 17	1 p. m.	9:10 p. m.	....	3	....	....	1	....	....	Hy. snow, 0.64 inch.
Dec. 20	9 a. m.	9:50 p. m.	1	....	....	....	1	....	....	Lt. rain and sleet, 0.57 inch.
Dec. 26	3:48 p. m.	7 p. m.	....	....	1	....	....	1	....	Lt. snow, tr. No sp. obs.
Dec. 28	3:40 a. m.	1 p. m.	1	....	....	....	1	....	....	Hy. rain, 0.63 inch.
Dec. 31	12:40 p. m.	7 p. m.	....	....	1	....	1	....	....	Hy. snow and sleet, 0.42 inch. No sp. obs.
1888.										
Jan. 1	D. n.	2.30 p. m.	1	....	....	....	1	....	....	Hy. rain, 0.85 inch.
Jan. 6	11:20 a. m.	5:45 p. m.	....	2	....	....	1	....	....	Lt. rain. No sp. obs.
Jan. 9	10:55 a. m.	D. n.	....	....	1	....	1	....	....	Lt. snow and rain, 0.31 inch. No sp. obs.
Jan. 13	D. n.	12:45 p. m.	1	....	....	....	1	....	....	Lt. rain and sleet, 0.70 inch.
Jan. 17	2:45 a. m.	5:30 p. m.	1	....	....	....	1	....	....	Lt. snow and sleet, 0.26 inch.
Jan. 23	1:35 p. m.	1:45 p. m.	....	....	1	....	....	1	1	Lt. snow, tr. No sp. obs.
Jan. 25	1:35 p. m.	8:10 p. m.	....	....	1	....	1	....	....	Hy. snow, 0.60 inch. No sp. obs.
Jan. 29	6 p. m.	8:35 p. m.	....	1	....	1	....	....	....	Lt. snow, 0.03 inch.
Jan. 31	1:55 p. m.	2:10 p. m.	....	....	1	1	....	....	....	Lt. rain, tr. No sp. obs.
Feb. 4	1:40 a. m.	9:10 p. m.	1	....	....	....	1	....	....	Lt. rain, 0.48 inch.
Feb. 7	6:20 a. m.	12:10 p. m.	1	....	....	....	....	1	....	Lt. rain, mist, 0.03 inch. No sp. obs.
Feb. 8	8:20 a. m.	12:15 p. m.	1	....	....	....	1	....	1	Lt. rain, 0.40 inch.
Feb. 9	6:25 a. m.	12:50 p. m.	1	....	....	....	....	1	....	Lt. snow, tr.
Feb. 10	All day.		1	....	....	....	1	....	....	Lt. snow and sleet, 0.16 inch.
Feb. 11	D. n.	4:40 p. m.	1	....	....	....	1	....	....	Sleet and rain, 0.42 inch.
Feb. 20	5:30 a. m.	5:07 p. m.	1	....	....	....	....	1	....	Lt. rain, 0.10 inch. No sp. obs.
Feb. 27	6:25 a. m.	11:30 a. m.	1	....	....	....	1	....	....	Lt. snow, 0.06 inch.
Mar. 1	1:15 p. m.	2:25 p. m.	....	....	1	1	....	....	....	Lt. rain, tr. No sp. obs.
Mar. 2	12:45 p. m.	12:46 p. m.	....	....	1	1	....	....	....	Do.
Mar. 5	6:15 a. m.	9:40 p. m.	1	....	....	....	1	....	....	Hy. snow, 0.42 inch.
Mar. 13	11:40 a. m.	8:30 p. m.	....	....	1	....	....	1	....	Lt. snow, tr.
Mar. 14	9 a. m.	10 a. m.	1	....	....	....	....	1	....	Do.
Mar. 16	5:45 p. m.	7:20 p. m.	....	1	....	1	....	....	....	Lt. rain.
Mar. 20	5:30 a. m.	2:15 p. m.	1	....	....	....	1	....	....	Lt. rain, 0.44 inch.
Mar. 21	1:35 p. m.	4:15 p. m.	....	....	1	....	1	....	....	Lt. rain, 0.50 inch. No sp. obs.
Mar. 22	2:55 p. m.	3:30 p. m.	....	....	1	....	....	1	....	Lt. snow, tr.
Mar. 24	4 a. m.	11:15 a. m.	1	....	....	....	....	1	....	Do.
Mar. 26	D. n.	11 a. m.	1	....	....	....	1	....	....	Hy. rain, 0.50 inch.
Mar. 26	2:40 p. m.	D. n.	....	3	....	....	1	....	....	Lt. rain, 0.19 inch.
Mar. 27	5:30 p. m.	D. n.	....	2	....	1	....	....	....	Lt. rain.
Mar. 29	8:50 a. m.	10:20 a. m.	1	....	....	....	....	1	....	Lt. rain, 0.21 inch. No sp. obs.
Mar. 31	9 p. m.	9:30 p. m.	....	6	....	1	....	....	....	
Apr. 5	5:20 a. m.	12:05 p. m.	1	....	....	....	1	....	....	Lt. rain and thunder.
Apr. 10	1:45 a. m.	6:40 p. m.	....	10	....	....	1	....	....	Lt. and hy. rain, 0.77 inch.
Apr. 12	12:28 p. m.	12:32 p. m.	....	½	....	....	....	1	....	Lt. rain, tr.
Apr. 14	Early a. m.	11:30 a. m.	1	....	....	....	1	....	....	Lt. rain.
Apr. 15	8:15 p. m.	11:20 p. m.	....	3	....	1	....	....	....	Lt. rain, 0.12 inch.
Apr. 16	7:40 a. m.	9:20 a. m.	1	....	....	....	1	....	....	Lt. rain, 0.05 inch.
Apr. 19	3:25 p. m.	3:35 p. m.	....	½	....	1	....	....	....	Lt. rain.
Apr. 23	D. n.	9:10 a. m.	1	....	....	....	1	....	....	Lt. rain, 0.34 inch.
May 1	7:10 a. m.	10:35 a. m.	1	....	....	....	1	....	....	Lt. rain, 0.10 inch.
May 4	8:10 p. m.	10:25 p. m.	....	5	....	1	....	....	....	Lt. rain.
May 8	10 a. m.	D. n.	....	1½	....	....	1	....	....	Do.
May 10	8:40 p. m.	10:45 p. m.	....	6	....	1	....	....	....	Do.

TABLE Q.—*Potential on days on which precipitation occurred at Washington, D. C., October* 1, 1887, *to August* 31, 1888—Continued.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative observed.	No observation.	Negative.	No negative.		
1888.										
May 11	6 a. m.	4:30 p. m.	1	....	....	....	1	....	....	Lt. rain, 0.27 inch.
May 12	3:45 p. m.	9:10 p. m.	....	....	1	....	....	1	....	Lt. rain, 0.55 inch. No sp. obs.
May 14	9:40 a. m.	11:35 a. m.	....	....	1	....	....	1	....	Lt. rain, 0.14 inch. No sp. obs.
May 18	3:45 a. m.	1:55 p. m.	1	....	....	....	1	....	....	Lt. rain, 0.37 inch.
May 23	2:30 a. m.	4:40 p. m.	1	....	....	....	....	1	....	Lt. rain, 0.74 inch. No sp. obs.
May 24	D. n.	7:45 p. m.	1	....	....	....	....	1	....	Lt. rain, 0.68 inch. No sp. obs.
May 25	3:05 p. m.	3:25 p. m.	....	2	....	1	....	....	....	Lt. rain.
May 26	4:50 p. m.	5:15 p. m.	....	8	....	....	1	....	....	Do.
May 30	8:40 a. m.	9:25 a. m.	1	....	....	....	....	1	....	Lt. rain, 0.03 inch. No sp. obs.
May 30	4:12 p. m.	8:15 p. m.	....	....	1	....	....	1	....	Lt. rain, 0.09 inch. No sp. obs.
May 31	4:30 a. m.	8:30 p. m.	1	....	....	....	1	....	....	Lt. rain, 0.45 inch.
June 14	4:40 p. m.	5:07 p. m.	....	¼	....	....	1	....	....	Hy. rain, 0.40 inch. Thunder.
June 16	4:03 p. m.	7:10 p. m.	....	....	1	....	....	1	....	Lt. rain, 0.22 inch. No sp. obs.
June 23	3:16 p. m.	5:35 p. m.	....	2	....	....	....	1	....	Lt. rain, 0.69 inch. No sp. obs.
June 26	11:25 a. m.	11:27 a. m.	....	....	1	....	....	1	....	Lt. rain, tr.
June 27	10:10 a. m.	8:10 p. m.	....	....	1	....	1	....	....	Lt. rain, 0.10 inch. No sp. obs.
June 28	D. n.	5:10 p. m.	1	....	....	....	1	....	....	Hy. rain, 1.34 inches.
June 29	D. n.	12:40 p. m.	1	....	....	....	1	....	....	Lt. rain, 0.53 inch.
July 5	2:15 p. m.	5:35 p. m.	....	....	1	....	1	....	....	Lt. rain, 0.02 inch. No sp. obs.
July 9	8:35 a. m.	3:20 p. m.	1	....	....	....	....	1	....	Lt. rain, 0.46 inch. No sp. obs.
July 10	D. n.	12 m	1	....	....	....	1	....	....	Lt. rain.
July 19	10:55 a. m.	7:50 p. m.	....	....	1	....	1	....	....	Lt. rain, 0.06 inch. No sp. obs.
July 30	12:05 p. m.	3:10 p. m.	....	1	....	....	1	....	....	Lt. rain.
Aug. 4	8:40 p. m.	8:50 p. m.	....	3½	....	1	....	....	....	Do.
Aug. 8	4:50 p. m.	8:20 p. m.	....	....	1	....	1	....	....	Hy. rain, 0.79 inch. Thunder. No sp. obs.
Aug. 17	1:58 p. m.	4:50 p. m.	....	....	1	....	....	1	1	Lt. rain, 0.03 inch. Thunder. No sp. obs.
Aug. 18	7:10 a. m.	9:47 a. m.	1	....	....	....	....	1	....	Lt. rain.
Aug. 18	5:45 p. m.	7:35 p. m.	....	7	....	1	....	....	....	Lt. rain, 0.17 inch.
Aug. 21	11:50 a. m.	6:20 p. m.	....	....	1	....	1	....	....	Lt. rain, 0.89 inch. No sp. obs.
Aug. 27	3:45 p. m.	6:10 p. m.	....	....	1	....	1	....	....	Lt. rain, 0.17 inch. Thunder. No sp. obs.
Aug. 31	1:52 p. m.	3:25 p. m.	....	....	1	....	1	....	....	Lt. rain, 0.08 inch. No sp. obs.
Total (96)			46	21	29	15	50	31	3	

NOTE.—Of the 31 during which no negative was observed, special observations were made during only 1 storm, and it was light rain (tr.).

Precipitation.	Before.			During.			Negative after.
	No observation.	Negative first observed.	No negative observed.	No observation.	Negative.	No negative.	
Rain (74)	34	19	21	13	38	23	2
Rain and sleet (4)	4	0	0	0	4	0	0
Rain and snow (1)	0	0	1	0	1	0	0
Sleet and snow (3)	2	0	1	0	3	0	0
Snow (14)	6	2	6	2	4	8	1

TABLE R.—*Potential on days on which precipitation occurred at Boston, Mass., December* 1, 1887, *to August* 31, 1888.

Date.	Remarks.
1887.	
Dec. 15	Rain began at 12 m. and continued during remainder of the day; potential positive at all regular observations, except 3 p. m., when it varied from positive to negative.
1888.	
Jan. 13	Snow began early a. m.; turned to sleet, then to rain during the evening; rain continued during the night; potential negative at 9 a. m. and 5 p. m.; positive at other regular observations.
Jan. 17	Snow 9:50 to 10:50 a. m., 4:30 p. m., and during night; potential positive all day, decreasing slowly.
Jan. 26	Snow began early a. m.; turned to rain before 4 a. m.; rain ended 10:15 a. m.; potential negative at 9 a. m.; positive at other regular observations.
Feb. 4	Snow began 12:50 p. m.; turned to sleet during evening; sleet continued during night; potential positive during day; insulation bad during p. m.
Feb. 8	Lt. rain 2:30 p. m. and during night; potential positive all day.
Feb. 10	Lt. snow 4:15 p. m. and during night; potential positive all day.
Feb. 11	Sleet 10:30 a. m. to 2:30 p. m.; snow 2:30 p. m. and during night; potential positive at 9 a. m. and 5 p. m.; negative 11 a. m., 1 and 3 p. m.
Feb. 20	Lt. rain 2 p. m. and during night; potential positive all day.
Feb. 25	Lt. snow 12:30 to 2:30 p. m.; sleet 2:30 to 3:30 p. m.; lt. rain 3:30 p. m. and during night; potential positive at 9 and 11 a. m. and 1 p. m.; negative at 3 and 5 p. m.
Mar. 12	Snow early a. m. and during night; potential positive at 9 a. m.; negative at 11 a. m. and 1, 3, and 5 p. m.
Mar. 13	Snow midnight to 10:45 a. m.; 4:30 p. m. and during night; potential positive all day.
Mar. 14	Snow midnight to 10:30 a. m.; potential positive all day.
Mar. 21	Lt. rain early a. m. and during night; potential positive 9 a. m. and 3 and 5 p. m.; negative at 11 a. m. and 1 p. m.
Mar. 26	Lt. snow 12:50 to 2:30 p. m.; rain 2:30 to 4:40 p. m.; sleet 4:40 p. m. and during night; potential positive 9 and 11 a. m., 1 and 3 p. m.; negative at 5 p. m.
Mar. 28	Lt. rain early a. m. to 10:30 a. m.; potential positive all day.
Mar. 29	Rain 11:30 a. m. to 12:55 p. m.; potential positive all day.
Apr. 2	Lt. rain early a. m. to 11:30 a. m.; potential negative at 9 a. m.; positive at all other observations.
Apr. 5	Lt. rain 2:55 p. m. and during night; potential positive at 9 and 11 a. m. and 1 p. m.; variable negative at 3 and 5 p. m.
Apr. 11	Lt. rain early a. m. to 10:30 a. m.; potential positive at all observations.
Apr. 12	Lt. rain 2:15 to 2:50 p. m.; 4:45 p. m. and during night; potential positive at 9 and 11 a. m. and 3 p. m.; negative at 1 and 5 p. m.
Apr. 14	Lt. rain 12:40 to 4:30 p. m.; potential variable negative to positive at 9 a. m. and 1 p. m.; negative at 3 p. m.; positive at 11 a. m. and 5 p. m.
Apr. 16	Rain 12:50 to 12:55 p. m.; potential high; negative at 1 p. m.; positive at other observations.
Apr. 18	Lt. rain 12 m. to 2:50 p. m.; potential negative at 11 a. m. and 1 p. m.; positive at other observations.
Apr. 20	Lt. rain 3:45 p. m. and during night; potential negative at 5 p. m.; positive at all other observations.
Apr. 21	Snow early a. m. to 10:30 a. m.; lt. rain 10:30 a. m. to 12:40 p. m.; potential negative at 11 a. m.; positive at all other observations.
May 1	Lt. rain 11:57 a. m. to 12:50 p. m.; potential positive at all observations.
May 5	Lt. rain early a. m. to 9:45 a. m.; potential positive at all observations.
May 9	Rain early a. m. to 10 a. m.; potential positive at all observations.
May 12	Lt. rain early a. m. to 12 m.; potential positive at all observations.
May 15	Lt. rain early a. m. to 1:10 p. m.; potential negative at 11 a. m.; positive at all other observations.
May 16	Light sprinkling rain after 5 p. m.; potential negative at 3 p. m.
May 17	Light sprinkling rain 1 to 5 p. m.; potential negative at 1, 3, and 5 p. m.
May 19	Lt. rain early a. m. to 4 p. m.; potential positive at all observations.
May 26	Lt. rain 8:55 a. m. to 12:40 p. m.; potential low positive at all observations.
May 28	Lt. rain 2 p. m. and during night; potential positive all day; insulation bad.
June 11	Rain 12:30 to 12:50 p. m.; potential positive at all observations.
June 14	Lt. rain 9:40 a. m. to 5:30 p. m.; potential positive at 9 a. m.; variable from positive to negative at all other observations.
June 15	Rain 9:10 to 10:20 a. m.; potential variable positive to negative at 9 a. m.; positive at all other observations.
June 20	Lt. rain 9:40 a. m. to 12:40 p. m.; potential variable positive to negative at 11 a. m.; positive at all other observations.
June 21	Lt. rain 12:40 to 1:30 p. m.; potential positive at all observations.
June 26	Lt. rain 2 to 6 p. m.; potential positive at all observations.
July 19	Lt. rain 8:50 to 11:15 a. m.; potential zero at 9 a. m.; variable positive to negative at 11 a. m.; positive at all other observations.
July 20	Rain 2:10 to 2:40 p. m.; potential positive at all observations.
July 23	Rain 4:20 to 4:28 p. m.; potential positive at all observations.
July 27	Lt. rain 8:55 a. m. to 3:40 p. m.; potential positive 9 a. m. and 5 p. m.; no observations at 11 a. m., 1 and 3 p. m.

TABLE R.—*Potential on days on which precipitation occurred at Boston, Mass., December* 1, 1887, *to August* 31, 1888—Continued.

Date.	Remarks.
1888.	
July 31	Potential variable positive from 7 to 11 a. m.; variable negative from 11 a. m. to 3 p. m.; variable positive from 3 to 11 p. m.; variable positive and negative from 11 p. m. to 3 a. m. of Aug. 1; variable positive all day of Aug. 1; lt. rain, b. 7:50 p. m. of July 31 and continued most of the night.
Aug. 4	Lt. rain from 8:45 to 8:55 a. m.; potential variable positive from 7 to 8:40 a. m.; variable positive and negative from 8:40 to 9 a. m.; variable positive all rest of the day.
Aug. 6	Lt. rain, b. d. n., e. 10:20 a. m.; lt. rain, b. 3:20 p. m., continued to d. n. of 7th; no record until 11 a. m. of 6th; variable positive and negative from 1 to 2 p. m.; negative from 4 to 6:30 p. m.; zero potential the rest of the time.
Aug. 9	Lt. rain, b. and e. d. n.; zero potential all night.
Aug. 12	Lt. rain from 9:40 a. m. to 1:10 p. m.; variable positive from 7 to 11 a. m.; steady positive the rest of the day.
Aug. 13	Rain, b. d. n., e. 11:20 a. m.; b. 2:40, e. 3:10 p. m.; steady positive all the time.
Aug. 16	Lt. rain, b. and e. d. n.; variable positive from 1 to 11 p. m. of 15th; variable negative from 11 p. m. of 15th to 1 a. m. of 16th; variable positive all day of 16th, except negative from 9:25 to 9:40 p. m.; lt. rain from 9:45 to 10 p. m.
Aug. 17	Variable positive from 6 to 11 a. m.; variable positive and negative from 11 a. m. to 11 p. m.; lt. rain from 2:45 to 4:05 p. m. and from 8:40 to 9:10 p. m.
Aug. 21	Potential zero during the nights of 20th, 21st, and also 21st, 22d; variable positive from 7 a. m. to 5 p. m. of 21st; hy. rain from 5:25 p. m. of 21st to 1:28 a. m. of 22d.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.		
1887.										
Dec. 15	12 m	D. n	----	----	1	----	1	----	----	Rain.
1888.										
Jan. 13	Early a. m.	D. n	1	----	----	----	1	----	----	Snow; sleet; rain.
Jan. 17	9:50 a. m.	10:50 a. m.	----	----	1	----	----	1	----	Snow.
Jan. 17	4:30 p. m.	D. n	----	----	1	----	----	1	----	Do.
Jan. 26	Early a. m.	10:15 a. m.	1	----	----	----	1	----	----	Snow and rain.
Feb. 4	12:50 p. m.	D. n	----	----	1	----	----	1	----	Snow and sleet.
Feb. 8	2:30 p. m.	D. n	----	----	1	----	----	1	----	Lt. rain.
Feb. 10	4:15 p. m.	D. n	----	----	1	----	----	1	----	Snow.
Feb. 11	10:30 a. m.	D. n	----	----	1	----	1	----	----	Sleet and snow.
Feb. 20	2 p. m	D. n	----	----	1	----	----	1	----	Rain.
Mar. 12	Early a. m.	----------	1	----	----	----	1	----	----	Snow.
Mar. 13	----------	10:45 a. m.	1	----	----	----	1	----	----	Do.
Mar. 14	Early a. m.	10:30 a. m.	1	----	----	----	----	1	----	Do.
Mar. 21	Early a. m.	D. n	1	----	----	----	1	----	----	Rain.
Mar. 26	12:50 p. m.	D. n	----	----	1	----	1	----	----	Snow; rain; sleet.
Mar. 28	Early a. m.	10:30 a. m.	1	----	----	----	----	1	----	Rain.
Mar. 29	11:30 a. m.	12:55 p. m.	----	----	1	----	----	1	----	Do.
Apr. 2	Early a. m.	11:30 a. m.	1	----	----	----	1	----	----	Do.
Apr. 5	2:55 p. m.	D. n	----	----	1	----	1	----	----	Do.
Apr. 11	Early a. m.	10:30 a. m.	1	----	----	----	----	1	----	Do.
Apr. 12	2:15 p. m.	2:50 p. m.	----	1¼	----	1	----	----	----	Do.
Apr. 12	4:45 p. m.	D. n	----	4¾	----	----	1	----	----	Do.
Apr. 14	12:40 p. m.	4:30 p. m.	----	3¾	----	----	1	----	----	Do.
Apr. 16	12:50 p. m.	12:55 p. m.	----	----	1	1	----	----	1	Do.
Apr. 18	12 m	2:50 p. m.	----	1	----	1	----	----	1	Do.
Apr. 20	3:45 p. m.	D. n	----	----	1	----	1	----	----	Do.
Apr. 21	Early a. m.	12:40 p. m.	1	----	----	----	1	----	----	Snow; rain.
May 1	11:57 a. m.	12:50 p. m.	----	----	1	----	----	1	----	Rain.
May 5	Early a. m.	9:45 a. m.	1	----	----	----	----	1	----	Do.
May 9	Early a. m.	10 a. m	1	----	----	----	----	1	----	Do.
May 12	Early a. m.	12 m	1	----	----	----	----	1	----	Do.
May 15	Early a. m.	1:10 p. m.	1	----	----	----	1	----	----	Do.
May 16	D. n	D. n	----	2¼	----	1	----	----	----	Do.
May 17	1 p. m	5 p. m	1	----	----	----	----	1	----	Do.
May 19	Early a. m.	4 p. m	1	----	----	----	----	1	----	Do.
May 26	8:55 a. m.	12:40 p. m.	1	----	----	----	----	1	----	Do.

TABLE R.—*Potential on days on which precipitation occurred at Boston, Mass., December* 1, 1887, *to August* 31, 1888—Continued.

Date.	Precipitation.		Before.			During.			Negative after.	Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.		
1888.										
May 28	2 p. m	D. n	....	....	1	....	....	1	....	Rain.
June 11	12:30 p. m	12:50 p. m	....	....	1	....	....	1	....	Do.
June 14	9:40 a. m	5:30 p. m	....	....	1	....	1	....	....	Do.
June 15	9:10 a. m	10:20 a. m	....	$\frac{1}{6}$	....	....	....	1	....	Do.
June 20	9:40 a. m	12:40 p. m	....	....	1	....	1	....	....	Do.
June 21	12:40 p. m	1:30 p. m	....	....	1	....	....	1	....	Do.
June 26	2 p. m	6 p. m	....	....	1	....	....	1	....	Do.
July 19	8:50 a. m	11:15 a. m	1	....	....	....	1	....	....	Do.
July 20	2:10 p. m	2:40 p. m	....	....	1	....	....	1	....	Do.
July 23	4:20 p. m	4:28 p. m	....	....	1	....	....	1	....	Do.
July 27	8:55 a. m	3:40 p. m	1	....	....	....	....	1	....	Do.
July 31	7:50 p. m	D. n	....	8	....	....	1	....	....	Rain. Photo. record begun.
July 4	8:45 a. m	8:55 a. m	....	$\frac{1}{2}$	....	....	1	....	....	Rain.
Aug. 6	Early a. m.	10:20 a. m	1	....	....	1	....	....	....	Do.
Aug. 6	3:20 p. m	D. n	....	$2\frac{1}{4}$	....	....	1	....	....	Do.
Aug. 12	9:40 a. m	1:10 p. m	....	....	1	....	....	1	....	Do.
Aug. 13	Early a. m.	11:20 a. m	....	....	1	....	....	1	....	Do.
Aug. 13	2:40 p. m	3:10 p. m	....	....	1	....	....	1	....	Do.
Aug. 16	D. n	D. n	....	1	....	....	....	1	....	Do.
Aug. 16	9:45 p. m	10 p. m	....	$\frac{1}{4}$	....	....	....	1	....	Do.
Aug. 17	2:40 p. m	9:10 p. m	....	4	....	....	1	....	1	Do.
Aug. 21	5:25 p. m	D. n	....	....	1	....	....	1	....	Hy. rain.
	Total (58)		20	12	26	5	23	30	....	

TABLE S.—*Potential before and during precipitation, St. Louis, Mo.*, 1861.

[A. Wislizenus, M. D., observer.]

Date.	Precipitation.		Before.			During.			Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.	
1861.									
Jan. 13	12 m	D. n	....	....	1	....	....	1	Lt. drizzling rain.
Jan. 15	11:45 a. m.	D. n	....	....	1	....	1	....	Hy. rain.
Jan. 16	8 a. m	10 a. m	....	....	1	....	....	1	Lt. snow.
Jan. 17	8 p. m	10 p. m	....	....	1	....	....	1	Do.
Jan. 23	12 m	D. n	....	....	1	....	....	1	Drizzling rain and hy. snow.
Feb. 1	D. n	10 a. m	1	....	....	....	1	....	Drizzling rain.
Feb. 2	11 a. m	11:05 a. m	....	....	1	....	....	1	Trace of snow.
Feb. 3	12 m	.....	....	....	1	....	....	1	Trace of snow; clear.
Feb. 10	8 a. m	11 a. m	....	....	1	....	1	....	Hy. rain and thunder.
Feb. 13	10 a. m	D. n	....	....	1	....	....	1	Light rain; mist.
Feb. 14	All day.		1	....	....	....	1	....	Light rain and snow.
Feb. 15	D. n	8 a. m	1	....	....	....	....	1	Lt. snow.
Feb. 16	All day.		1	....	....	....	....	1	Do.
Feb. 17	D. n	2 p. m	1	....	....	....	....	1	Do.
Feb. 18	7 p. m	.....	....	....	1	1	....	....	Lt. rain.
Feb. 23	4 a. m	5 a. m	....	16	....	1	....	....	Hail, rain, and thunder; gale.
Feb. 24	6:45 a. m	.....	1	....	....	....	....	1	Lt. snowflakes.
Mar. 3	D. n	1 p. m	1	....	....	....	1	....	Lt. rain.
Mar. 8	4 a. m	12 m	1	....	....	....	1	....	Do.
Mar. 16	D. n	Early a. m.	1	....	....	....	1	....	Do.
Mar. 17	9 a. m	.....	....	....	1	....	....	1	Lt. snowflakes.
Mar. 19	6 p. m	D. n	....	....	1	....	1	....	Lt. rain and snow.
Mar. 25	9 a. m	D. n	....	....	1	....	1	....	Thunder and hy. rain.
Mar. 26	D. n	11 a. m	1	....	....	....	1	....	Do.
Mar. 29	7 a. m	3 p. m	....	1	....	....	1	....	Thunder and rain.
Apr. 3	D. n	5 p. m	1	....	....	....	1	....	Lt. rain.
Apr. 6	6 a. m	2 p. m	1	....	....	....	....	1	Do.
Apr. 7	10 a. m	6 p. m	....	....	1	....	1	....	Lt. rain; thunder.
Apr. 8	10 a. m	11 a. m	....	....	1	....	....	1	Lt. rain.
Apr. 11	All day.		1	....	....	....	....	1	Do.
Apr. 12	6 a. m	3:30 p. m	1	....	....	....	1	....	Hy. rain.
Apr. 20	1 p. m	.....	....	....	1	1	....	....	Lt. shower; negative after rain.
Apr. 23	6 a. m	4 p. m	1	....	....	....	1	....	Lt. rain; thunder.
Apr. 27	D. n	2 p. m	1	....	....	....	....	1	Lt rain.
Apr. 29	8 p. m	9 p. m	....	....	1	1	....	....	Do.
May 3	3 p. m	.....	....	....	1	....	1	....	Do.
May 5	7 a. m	2:30 p. m	....	1	....	....	1	....	Lt. rain; thunder.
May 6	3 p. m	.....	....	3	....	....	1	....	Lt. rain.
May 9	9 p. m	D. n	....	1	....	....	1	....	Lt. rain; thunder.
May 11	D. n	9 a. m	1	....	....	....	1	....	Do.
May 11	9 p. m	D. n	....	....	1	....	....	1	Lt. rain; mist.
May 12	D. n	3:45 p. m	1	....	....	....	1	....	Lt. rain, mist, and thunder.
May 19	3 p. m	5 p. m	....	....	1	....	....	1	Lt. rain.
May 20	12 m	.....	....	....	1	....	....	1	Do.
May 23	8:45 p. m	9 p. m	....	....	1	....	1	....	Do.
May 24	9 p. m	10 p. m	....	2	....	....	1	....	Thunder and rain.
May 29	8 a. m	2 p. m	....	....	1	....	....	1	Lt. rain.
May 31	8:30 a. m	1 p. m	....	....	1	....	....	1	Do.
June 1	5:30 a. m	9 a. m	1	....	....	....	....	1	Lt. rain; thunder.
June 1	8 p. m	9 p. m	....	....	1	....	....	1	Lt. rain.
June 3	All day.		1	....	....	....	....	1	Do.
June 4	6 p. m	7 p. m	....	....	1	....	1	....	Thunder and rain.
June 6	7 a. m	4 p. m	....	....	1	....	1	....	Do.
June 7	2:30 p. m	4 p. m	....	½	....	....	1	....	Hy. rain and thunder.
June 11	1 p. m	7 p. m	....	....	1	....	1	....	Do.
June 23	5:45 a. m	11 a. m	1	....	....	....	....	1	Lt. rain; mist.
June 24	12 m	.....	....	....	1	....	....	1	Lt. rain.
June 25	12 m	12:30 p. m	....	....	1	....	....	1	Do.
June 27	11 a. m	11:15 a. m	....	....	1	....	....	1	Do.
June 28	7 a. m	9:30 a. m	....	....	1	....	....	1	Do.
June 29	All day.		1	....	....	....	....	1	Do.
July 5	12 m	6 p. m	....	....	1	....	1	....	Thunder and rain.
July 7	5 p. m	9 p. m	....	....	1	....	1	....	Do.
July 15	2 p. m	3 p. m	....	....	1	1	....	....	Lt. rain.
July 19	8 a. m	9 a. m	....	....	1	1	....	....	Do.

TABLE S.—*Potential before and during precipitation, St. Louis, Mo.*, 1861—Continued.

Date.	Precipitation.		Before.			During.			Remarks.
	Began.	Ended.	No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.	
1861.									
July 21	12 m	4 p. m	....	....	1	1	....	....	Trace of rain.
July 28	4 p. m	.....	....	....	1	....	1	....	Thunder.
Aug. 5	1 p. m	1:15 p. m	....	2	....	....	1	....	Thunder, rain, and gale.
Aug. 8	12:15 p. m	4 p. m	....	....	1	....	1	....	Thunder; rain.
Aug. 12	3 p. m	.....	....	....	1	....	....	1	Lt. rain; mist.
Aug. 19	D. n	11 a. m	1	....	....	....	1	....	Lt. rain.
Aug. 21	3 p. m	D. n	....	....	1	....	1	....	Thunderstorm and rain.
Sept. 2	9:30 p. m	D. n	....	....	1	....	1	....	Do.
Sept. 3	1 p. m	2 p. m	....	....	1	1	....	....	Lt. rain.
Sept. 10	7 p. m	D. n	....	....	1	....	....	1	Lt. rain; zero potential.
Sept. 14	11 a. m	12 m	....	....	1	1	....	....	Thunder and rain.
Sept. 15	7 p. m	10 p. m	....	....	1	....	....	1	Thunder and rain; zero potential.
Sept. 20	3 p. m	.....	....	....	1	....	....	1	Lt. rain, tr.
Sept. 25	3 p. m	12 mid	....	....	1	....	....	1	Lt. rain.
Oct. 2	D. n	10 a. m	1	....	....	....	....	1	Lt. rain; zero potential.
Oct. 4	5 p. m	D. n	....	....	1	....	....	1	Do.
Oct. 5	All day.		1	....	....	....	1	....	Lt. rain; thunder.
Oct. 10	2 p. m	D. n	....	....	1	....	....	1	Lt. rain; zero potential.
Oct. 15	6 p. m	D. n	....	....	1	....	....	1	Do.
Oct. 16	D. n	8 a. m	1	....	....	....	1	....	Lt. rain.
Oct. 17	3:30 p. m	4 p. m	....	....	1	....	....	1	Lt. rain, zero potential.
Oct. 22	11 a. m	12 m	....	....	1	....	....	1	Lt. rain.
Oct. 25	11 a. m	3 p. m	....	....	1	....	....	1	Do.
Nov. 3	7 a. m	7:15 a. m	....	....	1	....	....	1	Do.
Nov. 19	11 a. m	7 p. m	....	....	1	....	1	....	Hy. rain; thunder.
Nov. 22	D. n	8 a. m	1	....	....	....	....	1	Lt. rain.
Dec. 3	9 a. m	10 a. m	....	....	1	....	....	1	Lt. snow.
Dec. 7	D. n	10 a. m	1	....	....	....	....	1	Lt. rain.
Dec. 21	3 p. m	D. n	....	....	1	....	1	....	Lt. snow.
Dec. 22	9:10 a. m	D. n	....	¼	....	....	1	....	Lt. rain and snow.
	Total (95)		28	9	58	9	40	46	

Precipitation.	Before.			During.		
	No observation.	Negative first observed.	No negative.	No observation.	Negative.	No negative.
Rains*	23	8	49	9	36	35
Snows	4	0	7	0	1	10
Rain and snow	1	1	2	0	3	1

* Zero potential in 7 cases.

TABLE T.—*Precipitation and negative potential at the Royal Observatory, Greenwich, England, 1879 to 1886, inclusive.*

Months.	Negative and precipitation.			Precipitation and no negative.				Negative and no precipitation.	Precipitation and no record.
	Rain.	Mist.	Snow.	Rain.	Rain less than .01.	Mist.	Snow.		
1879.									
January	0	0	0	0	0	0	0	0	0
February	11	0	2	1	0	0	2	0	0
March	12	0	3	0	1	2	1	1	4
April	14	0	1	2	3	0	1	3	0
May	14	0	0	3	4	0	1	2	0
June	14	0	0	7	3	0	0	0	0
July	13	0	0	6	3	0	0	1	0
August	14	0	0	5	4	2	0	1	0
September	10	0	0	3	5	1	0	1	0
October	3	0	0	6	9	1	0	1	0
November	5	0	3	1	2	1	3	3	0
December	5	0	2	2	6	0	3	0	1
Total	115	0	11	36	40	7	11	13	5
1880.									
January	4	0	1	1	4	0	1	1	0
February	9	0	0	7	2	0	0	0	1
March	4	0	0	1	2	0	0	3	0
April	15	0	0	2	5	0	0	1	0
May	9	0	0	0	0	1	0	7	0
June	20	0	0	0	1	0	0	1	0
July	21	0	0	5	1	0	0	2	0
August	11	0	0	0	1	0	0	7	0
September	12	0	0	2	2	1	0	3	0
October	18	0	0	0	2	1	0	2	0
November	8	0	0	3	2	4	2	1	0
December	12	0	1	2	3	0	1	1	0
Total	143	0	2	23	25	7	4	29	1
1881.									
January	0	0	1	0	1	0	1	0	16
February	11	0	2	3	0	1	3	1	0
March	8	0	3	1	1	1	1	2	0
April	10	0	1	1	0	1	0	4	2
May	18	0	0	0	0	0	0	5	0
June	10	0	0	0	2	2	0	8	2
July	22	0	0	0	1	1	0	4	0
August	18	0	0	1	1	0	0	8	0
September	17	0	0	4	2	2	0	1	1
October	9	0	0	1	3	0	0	0	7
November	8	0	0	6	7	2	0	0	0
December	13	0	0	4	2	4	0	1	0
Total	144	0	7	21	20	14	5	34	28
1882.									
January	4	0	0	3	5	0	0	3	2
February	6	0	0	2	6	2	0	2	0
March	10	0	0	2	4	4	0	4	0
April	15	0	0	1	4	1	0	1	0
May	13	0	0	0	3	1	0	7	0
June	19	0	0	1	2	1	0	3	2
July	13	0	0	6	3	2	0	0	0
August	15	0	0	3	2	1	0	6	0
September	11	0	0	5	2	4	0	2	0
October	20	0	0	4	2	2	0	0	1
November	18	0	0	3	2	2	0	1	0
December	9	0	2	7	3	2	0	0	0
Total	153	0	2	37	38	22	0	29	5
1883.									
January	11	0	0	5	3	0	0	1	0
February	12	0	0	3	3	3	0	0	0
March	5	0	5	3	2	3	3	1	2
April	10	1	1	1	0	3	0	4	1
May	11	0	0	0	1	4	0	4	1
June	13	0	0	2	1	2	0	4	1
July	16	0	0	1	5	0	0	2	1
August	15	0	0	1	5	6	0	2	0
September	13	0	0	2	4	3	0	0	3
October	11	0	0	2	4	5	0	3	0
November	15	0	0	4	4	3	0	0	0
December	9	0	1	6	6	1	1	1	1
Total	141	1	7	30	38	33	4	22	10

TABLE T.—*Precipitation and negative potential at the Royal Observatory, Greenwich, England, 1879 to 1886, inclusive*—Continued.

Months.	Negative and precipitation.			Precipitation and no negative.				Negative and no precipitation.	Precipitation and no record.
	Rain.	Mist.	Snow.	Rain.	Rain less than .01.	Mist.	Snow.		
1884.									
January	8	0	1	5	4	1	1	0	0
February	11	0	0	2	5	1	1	0	0
March	10	1	0	1	3	3	0	0	0
April	15	0	0	1	5	0	1	1	0
May	7	0	0	1	1	2	0	0	4
June	16	0	0	1	1	1	0	5	0
July	20	0	0	1	5	3	0	0	0
August	11	0	0	4	1	6	0	0	0
September	7	0	0	5	3	12	0	0	0
October	8	0	0	5	4	4	0	0	0
November	7	0	0	2	5	5	0	0	2
December	9	0	0	8	3	0	2	0	0
Total	129	1	1	36	40	38	5	6	6
1885.									
January	7	0	1	6	2	1	1	0	0
February	15	0	0	0	5	1	0	0	0
March	6	1	1	2	2	3	0	2	0
April	14	0	0	0	0	5	0	1	0
May	21	1	0	1	1	0	0	0	0
June	7	1	0	3	3	1	0	4	0
July	4	5	0	1	2	5	0	4	0
August	13	0	0	2	2	2	0	2	0
September	12	0	0	6	0	0	0	0	5
October	10	0	0	0	1	1	0	0	14
November	9	0	0	5	7	2	0	1	0
December	7	0	0	2	7	3	1	0	0
Total	125	8	2	28	32	24	2	14	19
1886.									
January	13	0	2	1	0	0	8	0	2
February	3	2	1	3	4	0	4	1	0
March	6	1	2	5	3	1	6	0	0
April	17	0	0	0	2	1	0	3	0
May	14	0	0	3	2	1	0	4	1
June	9	1	0	1	2	1	0	6	0
July	14	2	0	0	4	2	0	4	0
August	6	3	0	5	0	6	0	1	0
September	7	4	0	3	3	4	0	0	0
October	10	1	0	3	7	4	0	1	0
November	11	0	0	5	2	2	0	0	1
December	18	0	2	0	0	3	1	0	1
Total	128	14	7	29	29	25	19	20	5

SUMMARY.

Year.	Negative and precipitation.			Precipitation and no negative.				Negative and no precipitation.	Precipitation and no record.
	Rain.	Mist.	Snow.	Rain.	Rain less than .01.	Mist.	Snow.		
1879	115	0	11	36	40	7	11	13	5
1880	143	0	2	23	25	7	4	29	1
1881	144	0	7	21	20	14	5	34	28
1882	153	0	2	37	38	22	0	29	5
1883	141	1	7	30	38	33	4	22	10
1884	129	1	1	36	40	38	5	6	6
1885	125	8	2	28	32	24	2	14	19
1886	128	14	7	29	29	25	19	20	5
Total	1078	24	39	240	262	170	50	167	79

TABLE U.—*Negative potentials without precipitation, Terre Haute, Ind., March* 30, 1887, *to August* 31, 1888.

Date.	Remarks.
1887.	
Mar. 30	Observations began 12:30 p. m.; positive until 3 p. m.; steady negative from 4 to 7 p. m., with threatening weather; lt. rain predicted by S. O.; rain in the Ohio Valley and Tennessee and in Illinois; station northeast of a low pressure.
Apr. 3	Observations from 10:30 a. m. to 12 m.; negative for a few minutes at 11:50 a. m., with fair weather; lt. rain predicted by S. O.; east of a low; rain in the lake region.
Apr. 4	Cloudy in a. m. with positive; W. br. winds; steady negative from 4 to 6:30 p. m., with W. gale and threatening; fair predicted by S. O.; southwest of a low and in northeast edge of a high; rain in the lower lakes.
Apr. 14	Variable positive and negative from 2:30 to 3:30 p. m.; steady positive rest of the day; threatening from 2:30 to 3 p. m.; fair predicted by S. O.; rain in Ohio, Tennessee, and on the lakes.
Apr. 15	Variable positive and negative all day; clouds varied from clear to threatening; W. br. to gale winds; fair by S. O.; rain on the lakes and in Arkansas.
Apr. 29	Variable positive all day, except for a few seconds, at 11:10 a. m., when it was negative; NW. gale to br. winds; perfectly clear; fair by S. O.; rain in the lake region.
May 3	Threatening with variable positive and negative from 9 to 10 a. m.; steady positive from then to 7 p. m., with cloudy weather; rain during the night.
May 20	Clear in a. m., with negative from 9 to 9:30 a. m.; then positive all day; fair in p. m.; rain on 21st.; S. O. predicted fair, followed by rain.
May 25	Negative for a short time at 3 p. m.; fair; S. O. predicted fair in northern with local rains in southern Indiana. This negative may have been due to an open window.
May 26	Negative from 8:50 to 9:05 a. m.; positive rest of the day; wind west; lt. at 9 a. m.; W. gale at 12 m.; clear in a. m.; fair in p. m.; rain in the east; S. O. fair.
May 27	Negative from 9 to 9:20 a. m.; perfectly clear in a. m.; NW. lt. winds; fair in p. m.; similar day to yesterday.
May 28	Clear in a. m.; fair in p. m.; conditions similiar to 26th and 27th; potential zero at 9 a. m.; negative at 3 p. m. for a few moments and positive the rest of the day; NW. lt. to fr. winds.
June 1	Threatening at 12 m.; thunder in the west from 12:45 to 1 p. m.; negative for a short time at 12:45 p. m. and again at 2:15 p. m.; positive the rest of the day; thunder in the west at 4:05 p. m., had no influence on the electrometer; rained during the night of the 2d.
June 2	Southwest of a low; rain in the lower lake region, Missouri Valley, and Tennessee; S. O. fair; threatening with negative for a few moments at 2:45, 3:31, and 4:18 p. m.; positive the rest of the time.
June 7	Threatening in p. m. with negative from 6 to 6:15 p. m.; positive the rest of the time; S. O. fair; rain in the upper lake region.
June 16	Perfectly clear; negative 9:36 to 9:37 a. m.; positive rest of the day; W. lt. to fresh winds; rain in the upper lake region; S. O. fair.
June 17	Perfectly clear; negative from 9:35 to 9:40 a. m.; W. lt.; rain on the lakes; S. O. fair; draft blew from room outward.
June 23	Threatening at 11 a. m.; negative at 11:30 a. m. and from 12 m. to 12:15 p. m.; positive rest of the day; W. gale winds; rain in the upper Mississippi Valley; S. O. fair.
June 25	Threatening at 11 a. m.; negative for a short time at 11:15 a. m.; positive rest of the time; rain in the Ohio Valley and Tennessee.
July 5	Fair weather; SW. lt.; negative at 6:01 and 6:38 p. m. while a R. R. train was passing; positive rest of the time; rain in the Ohio Valley, Tennessee, and lake region; S. O. fair.
July 9	Negative for a few moments at 12 m.; W. fr., and cloudy; NW. gale at 5 p. m.; rain in the Ohio Valley, and Tennessee, and the lake region; S. O. fair; station south of a low.
July 14	Negative from 12:36 to 12:41 p. m.; positive the rest of the time; clear weather; W. lt. winds; rain in Michigan; S. O. fair.
July 16	Temperature 100°; negative with an occasional positive from 1 to 7 p. m.; the wind was gusty from lt. to fresh and variable in direction, SW., NW., W., E., SE., and S.; threatened at 4 p. m. for a short time; rain in the lake region and upper Mississippi Valley; S. O. fair.
July 19	Threatening with negative at 10:55 and 11:12 a. m.; positive the rest of the time; NE. fresh winds; rain in Tennessee and upper lake region.
July 26	Clear all day with about one-tenth clouds; negative at 10:51, 10:56, 10:58, and at 11:40 a. m., and from 12:45 to 3 p. m., and at 5 p. m.; positive the rest of the time; it seemed that the change of the potential was due to the R. R. train passing; W. lt. winds; rain in Kentucky, Tennessee, and Michigan; S. O. fair.
July 27	Negative from 10:35 to 10:40 a. m. and from 1 to 1:15 and at 2:50 p. m.; positive the rest of the time; fair weather; lt. variable winds; rain in the Ohio Valley, Kentucky, Tennessee, and Michigan; S. O. fair.
July 28	Positive all day; negative at 6:50 p. m. while a train was passing; clear weather; N. lt. winds.
July 29	Negative at 12:10 p. m. while a train was passing; clear weather; rain in the Mississippi Valley, Tennessee, and Michigan; S. O. fair.
July 30	Clear day; lt. haze; fresh NW. winds; negative at 10:35 a. m. and from 11:10 to 11:14 a. m., while trains were passing; rain in the Ohio Valley and lake region; S. O. fair.
Aug. 2	Perfectly clear; NE. to E. gale to brisk winds; negative at 10 and 11 a. m., 1, and 3:30 to 3:45 p. m., and at 4:30 p. m.; positive at 9 a. m., 12 m., and 3 and 4 p. m.; rain in Ky., Tenn., and Mich.; S. O. fair.
Aug. 3	Clear day; negative from 12 m. to 1 p. m. and at 6 p. m.; lt. E. winds; rain all around except in the Ohio Valley; S. O. fair.

TABLE U.—*Negative potentials without precipitation, Terre Haute, Ind., March* 30, 1887, *to August* 31, 1888—Continued.

Date.	Remarks.
1887.	
Aug. 9	Clear weather; SE. lt. winds; variable positive and negative from 4 to 6.30 p. m.; once the negative seemed to be the result of a passing train, but at other times it was negative when no train was passing; rain in the upper lakes; S. O. fair.
Aug. 14	Variable positive and negative, with threatening weather after 4 p. m.; rain in the Ohio Valley and lakes, at Indianapolis and Springfield; S. O. lt. rain.
Aug. 18	Threatening; negative at 3 p. m. while a train was passing; rain in the lower lake region; S. O. fair.
Aug. 19	Clear day; negative at 6 p. m. while a train was passing; S. O. fair.
Aug. 20	Hazy weather; negative all afternoon; lt. W. winds; rain on the 21st.
Aug. 30	Negative from 5:30 to 5:55 p. m. and at 6:15 p. m.; cir.-str. clouds forming; rain in Missouri; southwest of a high.
Sept. 1	Negative for 5 minutes at 9 a. m. and from 5:50 to 5:55 p. m.; positive the rest of the day; rain in the lake region and Missouri Valley; S. O. fair, followed by rain.
Sept. 2	Negative at 10:35 a. m.; fair weather; SW. fr.
Sept. 3	Threatening, with negative from 9 to 9:10 a. m.; S. O. lt. rain.
Sept. 5	Negative from 10:15 to 10:45 a. m.; cir.-cu. clouds; rain in the upper Mississippi Valley and lake region.
Sept. 8	Negative for a few moments at 3:16 p. m. while a train was passing; varied from negative to positive from 3:30 to 4 p. m.; rain in Ohio and Michigan; S. O. fair.
Sept. 10	Threatening, with negative at 11 a. m.; rain in Ohio Valley and lake region and at Indianapolis; S. O. fair.
Sept. 23	Negative at 1, 3:05, and 3:12 p. m.; N. fr. cloudy; rain all around.
Oct. 5	Potential varied from positive to negative from 9 to 10 a. m.; clear weather; light variable wind; station east of high; train was switching in yard adjoining the Institute; generally clear at surrounding stations.
Oct. 6	Potential varied from positive to negative during whole evening; cloudy weather; light S. wind; station neither in a high nor a low; trains passing seemed to have no effect on electrometer readings; rain fell in Upper Miss. Valley and at Chicago after 3 p. m.
Oct. 7	Potential varied from positive to negative from 11 a. m. to 1 p. m.; fair in a. m., cloudy in p. m.; fresh S. wind; station east of low; rain fell in Michigan all day.
Oct. 8	Potential varied from positive to negative 9 a. m. to 12 m.; cloudy weather; light S. wind; station south of low; rain fell at Springfield and Chicago, Ill., and throughout the Northwest.
Oct. 18	Potential varied from positive to negative from 9 to 9:30 a. m.; cloudy, threatening weather; light variable wind; station neither in a high nor a low; rain fell in Tennessee all day and in Michigan during afternoon.
Oct. 21	Potential variable from positive to negative all day; generally clear weather; high W. to NW. wind; station west of low; light rain at Chicago before 3 p. m.
Oct. 22	Potential negative at 9 a. m.; cloudy, threatening weather; light E. to S. wind; station neither in a high nor a low; lt. rain at St. Louis all day; heavy rain at Chicago after 3 p. m.
Oct. 29	Potential variable positive to negative all morning; cloudy, threatening weather; high N. to NW. wind; station south of a high; lt. rain at Indianapolis, Cincinnati, Columbus, and Chicago all day.
Oct. 31	Potential varied from positive to negative after 5:45 p. m.; clear weather; light S. wind; station neither in a high nor a low; potential became negative about sunset, as smoke settled over the city and haze and fog began to form; generally clear weather at surrounding stations.
Nov. 1	Potential varied from positive to negative about 5 p. m. and after clear weather; light SE. wind; potential began to vary about sunset, when fog, haze, and smoke began to form; generally clear weather at surrounding stations.
Nov. 2	Potential variable from positive to negative about 9 a. m. and from 5 to 7:15 p. m.; station neither in high nor low; clear weather; light S. wind; light fog and haze in a. m. and again at night; clear during middle of day; generally clear at surrounding stations.
Nov. 3	Potential variable positive to negative about 3 p. m.; hazy weather; light S. wind; station south of a low; generally clear at surrounding stations.
Nov. 4	Potential varied from positive to negative about 3 p. m.; clear weather; brisk NW. wind; station east of high; lt. rain at all Michigan stations during the whole day; clear at nearer stations.
Nov. 5	Potential variable from positive to negative 9 to 10 a. m.; clear day; foggy in a. m.; light SW. wind; station neither in high nor low; clear at surrounding stations.
Nov. 6	Potential negative at 4:05 p. m.; clear weather; light SW. wind; station neither in high nor low; clear at surrounding stations.
Nov. 8	Potential variable positive to negative 3 to 4:30 p. m.; hazy weather; light N. wind; station neither in high nor low; clear at surrounding stations.
Nov. 12	Potential variable positive to negative all day; clear weather; light N. wind; station south of a high; generally clear at surrounding stations.
Nov. 13	Potential negative at 5 p. m.; cloudy, threatening weather; fresh S. wind; station south of a low; cloudy at neighboring stations; light rain in Michigan during afternoon.
Nov. 14	Potential variable from positive to negative during the afternoon; cloudy, threatening weather; fresh W. wind; station south of a low; light rain at Indianapolis and Nashville during the day.

TABLE U.—*Negative potentials without precipitation, Terre Haute, Ind., March* 30, 1887, *to August* 31, 1888—Continued.

Date.	Remarks.
1887.	
Nov. 17	Potential variable positive to negative 11:30 a. m. to 12:30 p. m.; clear weather; brisk W. wind; station neither in a high nor a low; lt. rain throughout Michiganall day; clear at nearer stations.
Nov. 18	Potential negative at 5 p. m.; hazy weather; fresh S. wind; station south of a low; lt. rain throughout the Northwest, Mich., Wis.; rain began here at 8:30 a. m. on 19th.
Nov. 22	Potential varied from positive to negative 4:30 to 5:30 p. m.; cloudy weather; brisk S. wind; station east of a low; light rain at Cairo, Ill., during the evening; cloudy at surrounding stations.
1888.	
Feb. 9	Potential variable from positive to negative 3 to 3:10 p. m.; fair weather; fresh N. wind; station within a high; lt. rain at Louisville, Ky.; Cairo, Ill.; St. Louis, Mo.; and in Michigan.
Feb. 17	Potential variable positive to negative about 5 p. m.; cloudy weather; fresh W. wind; station south of a low; lt. rain at St. Louis about noon.
Mar. 2	Potential variable positive to negative 10 a. m. to 12:30 p. m.; cloudy, threatening weather; brisk to high W. wind; station south of a low; heavy snow at all surrounding stations.
Mar. 28	Potential negative at 9 a. m.; cloudy weather; gentle N. wind; station neither in a high nor a low; rain at all surrounding stations during the whole day.
Apr. 12	Potential negative at 9 a. m.; clear weather; fresh N. wind; station within a high; generally clear weather at surrounding stations.
Apr. 20	Potential negative about 1 p. m.; cloudy weather; fresh N. wind; station within a high; lt. rain at Chicago all day; clear at southern stations.
Apr. 23	Potential negative about 1 p. m.; clear weather; brisk N. wind; station neither in a high nor a low; cloudy at surrounding stations.
Apr. 24	Potential variable positive to negative 10 to 11 a. m.; clear weather; light N. wind; station south of a high; generally clear at surrounding stations.
Apr. 26	Potential variable positive to negative 9 a. m. to 1 p. m.; hazy weather; fresh S. wind; station neither in a high nor a low; lt. rain at Springfield, Ill., and St. Louis about noon.
Apr. 28	Potential negative at 11 a. m.; clear with light haze; light SW. wind; station neither in a high nor a low; rain fell all day in Mississippi valley.
May 19	Potential negative at 9 a. m.; fair weather; fresh N. wind; station within a high; rain fell in Tennessee during the morning.
May 23	Potential negative 9. a. m. to 1 p. m.; cloudy, threatening weather; fresh SE. wind; station within a low; rain fell at all surrounding stations during the day.
June 13	Potential negative at 9 and 11 a. m.; fair weather; brisk southerly wind; station neither in a high nor a low; rain fell at Chicago and in Tennessee during the day.
June 25	Potential negative at 9 a. m.; threatening weather; light S. wind; station neither in a high nor a low; rain fell at all surrounding stations during the day.
July 18	Potential negative about 5 p. m.; fair weather; fresh W. wind; station south of a low; rain fell at all surrounding stations during the day.
July 26	Potential negative at 5 p. m.; threatening weather; fresh NE. wind; station neither in a high nor a low; rain fell at Springfield, Ill., and in Tennessee during the day.
Aug. 1	Potential negative at 5 p. m.; threatening weather; fresh SW. wind; station south of high; rain at surrounding stations during the day; thunderstorm raging in sight of station; no precipitation here.
Aug. 14	Potential variable positive to negative at 5 p. m.; cloudy weather; lt. SW. wind; station west of a high; rain at Chicago and in upper lake region during the afternoon.
Aug. 15	Potential variable positive to negative about 5 p. m.; cloudy weather; fresh S. wind; station neither in a high nor a low; rain at Memphis and Chicago during the day.
Aug. 21	Potential variable positive to negative at 5 p. m.; cloudy weather; light NW. wind; station north of a low; heavy rain at Indianapolis and stations east all day.
Aug. 31	Potential negative at 11 a. m. and 1 p. m.; cloudy weather; gentle variable wind; station west of a low; rain fell at Cincinnati, Louisville, and Columbus; heavy rain at Indianapolis during the early morning.

TABLE V.—*Negative potentials without precipitation, Ithaca, N. Y., October, 1887, to August, 1888.*

Date.	Remarks.
1887.	
Oct. 27	Potential negative at 9 a. m., positive at other observations; threatening weather; fresh SE. wind all day; station in anticyclonic area; from 3:15 to 4:10 p. m. rain was seen falling ESE. of station; rain fell at Albany, N. Y., and in Canadian lower lake regions between 7 a. m. and 3 p. m.
Nov. 12	Potential negative from 9 to 9:30 a. m.; cloudy weather; high NW. wind; station west of an area of low pressure; rain ended before 7 a. m. at this station; rain fell in Canadian lower lake regions between 7 a. m. and 3 p. m.
Nov. 16	Potential negative at 9 a. m.; cloudy weather; brisk NW. wind; station east of a low; precipitation in the upper lake regions and at Montreal, Canada, between 7 a. m. and 3 p. m.
Nov. 23	Potential variable positive to negative from 10:30 a. m. to 1 p. m.; hazy weather; gentle S. wind; station in anticyclonic area; precipitation at Rochester and Albany, N. Y., between 7 a. m. and 3 p. m.
Nov. 27	Potential negative from 9 a. m. until 1 p. m.; fair weather; fresh S. wind; station south of a low; precipitation quite heavy throughout the lower lake regions during the whole day.
Nov. 29	Potential variable from positive to negative all day; generally clear weather; fresh NW. wind; station within anticyclonic area; snow fell at Erie, Pa., Oswego, N. Y., and at Canadian lower lake stations all day.
Dec. 6	Potential negative from 2:15 to 2:54 p. m.; clear weather; light S. wind; station north of a high; rain before 7 a. m. at Buffalo, N. Y.; generally clear at surrounding stations during the day.
Dec. 16	Potential negative all day; cloudy weather; brisk NW. wind; station between two lows; precipitation at this station during early a. m.; cloudy weather at surrounding stations; rain on 17th at Buffalo, N. Y., Erie, Pa., and Cleveland, Ohio.
Dec. 19	Potential negative at 10:50 a. m. and 12:05 p. m.; positive at all other times during the day; cloudy weather; brisk NW. wind; station between two lows; snow fell all day at Canadian lower lake stations.
Dec. 21	Potential negative all day; cloudy, threatening weather; brisk NW. wind; station west of a low; snow fell all day at Oswego, Rochester and Buffalo, N. Y., Erie, Pa., and Canadian lower lake stations.
1888.	
Feb. 21	Potential variable positive to negative all day; cloudy weather; fresh N. wind; station south of a low; snow fell from 7 a. m. until 3 p. m. at Oswego, N. Y., and Canadian lower lake stations.
Feb. 28	Variable potential from positive to negative 11 a. m. to 7 p. m.; cloudy weather; brisk NW. wind; station north of a high; snow fell all day within sight of the station, but none fell at the station; snow fell all day at Canadian lower lake stations.
Feb. 29	Potential variable from positive to negative all day; light N. wind; station neither in a high nor a low; snow fell at Canadian lower lake stations from 7 a. m. to 3 p. m.
Mar. 15	Potential variable from positive to negative from 9 to 10:30 a. m.; positive remainder of day; cloudy weather; fresh N. wind; station north of a high; snow at Canadian lower lake stations at intervals during the day.
Mar. 20	Potential variable from positive to negative all day; cloudy, threatening weather; brisk S. wind; station east of a low; rain fell at Oswego, Rochester, and Buffalo, N. Y., Erie, Pa., and at all Canadian lower lake stations during the whole day.
Mar. 21	Potential variable from positive to negative all day; cloudy, threatening weather; brisk to high S. and NW. wind; station east and south of a low; lt. snow and rain at Oswego, Rochester and Buffalo, N. Y., and Erie, Pa.; snow at Canadian lower lake stations during the whole day.
Mar. 23	Potential variable positive to negative all day; fair weather; brisk NW. wind; station west of a low; lt. snow at Oswego, Rochester, and Buffalo during the whole day.
Mar. 24	Potential variable from positive to negative all day; fair weather; brisk NW. wind; station west of a low; lt. snow at Oswego, Rochester, and Buffalo, N. Y., from 7 a. m. to 3 p. m.; snow continued at Oswego after 3 p. m.
Mar. 29	Potential negative all day; cloudy to clear weather; brisk NW. wind; station west of a low; lt. snow all day at Rochester, N. Y., and Toronto, Canada.
Mar. 31	Potential negative all day; cloudy to clear weather; brisk NW. wind; station west of a low; light snow from early a. m. to 3 p. m. at Rochester and Canadian lower lake stations.
Apr. 4	Potential variable from positive to negative all day; clear weather; fresh NW. wind; station west of a high; rain in upper lake region during the afternoon; rain at this station began at 9:15 a. m. of 5th.
Apr. 6	Potential variable from positive to negative all day; clear weather; brisk NW. wind; station west of a low; generally clear weather at surrounding stations; faint aurora was observed during the night.
Apr. 7	Potential negative all day; clear weather; brisk NW. wind; station east of a high; light rain at Oswego, N. Y., between 7 a. m. and 3 p. m.
Apr. 8	Potential negative all day; clear weather; fresh to brisk NW. wind; station east of a high; quite heavy rainfall between 9 a. m. and 3 p. m. at Rochester and Oswego, N. Y.
Apr. 11	Potential variable from positive to negative all day; cloudy weather; brisk NW. wind; station west of a low; lt. rain at Oswego, Rochester, and Buffalo, N. Y., Erie, Pa., and Canadian lower lake stations between 7 a. m. and 3 p. m.

TABLE V.—*Negative potentials without precipitation, Ithaca, N. Y., October, 1887, to August, 1888*—Continued.

Date.	Remarks.
1888.	
Apr. 13	Potential variable from positive to negative all day; clear in a. m.; cloudy at night; fresh NW. wind during a. m.; light S. wind during p. m.; station east of a low; lt. rain at Canadian lower lake stations during the afternoon and evening.
Apr. 15	Potential negative all day; cloudy weather; fresh NW. wind; station east of a low; lt. rain and snow at Albany, N. Y., Erie, Pa., and Ohio lower lake stations during the morning and afternoon.
Apr. 16	Potential variable from positive to negative all day; clear to fair weather; brisk NW. wind; station west of a low; lt. rain at New York city and stations in its vicinity between 7 a. m. and 3 p. m.; faint aurora at night.
Apr. 17	Potential nagative all day; clear to cloudy weather; fresh NW. wind; station east of low; lt. rain and snow at all Canadian and New York lower lake stations during morning and evening.
Apr. 22	Potential variable from positive to negative all day; clear to fair weather; fresh NW. wind; station between two lows; snow fell all day about twenty miles west of station; no snow at lower lake stations.
Apr. 23	Potential variable from positive to negative all day; fair to cloudy weather; brisk NW. wind; station west of a low; snow fell all day about twenty miles west of station; also at New York city and stations in that vicinity.
Apr. 25	Potential variable from positive to negative all day; clear weather; light N. wind; station north of a high; no precipitation recorded at surrounding stations; cloudy weather at Canadian lower lake stations.
Apr. 26	Potential variable from positive to negative all day; clear weather; light NW. wind; station west of a high; fair weather at surrounding stations.
Apr. 27	Potential variable from positive to negative all day; clear weather; light NW. wind; station in anticyclonic area; clear at surrounding stations.
Apr. 28	Potential negative 9 to 9:30 a. m.; clear weather; light NW. wind; station neither in high nor low; clear at surrounding stations.
May 5	Variable positive to negative during p. m.; fair weather; fresh to brisk W. wind; station south of low; fair at surrounding stations; rain along Atlantic coast.
May 6	Negative at 1 p. m.; clear weather; fresh N. wind; station north of high; fair at surrounding stations.
May 7	Variable positive to negative during p. m.; cloudy weather; fresh NW. wind; station east of low; rain at nearly all the Canadian, New York, and Ohio lower lake stations from 9 a. m. to 3 p. m.
May 17	Variable positive to negative all day; fair weather; fresh N. wind; station north of high; rain general over whole country.
May 19	Variable positive to negative all day; cloudy, threatening weather; fresh NW. wind; station west of low; cloudy, threatening weather at surrounding stations; heavy rains at all stations before 7 a. m.
May 21	Variable positive to negative during the day; positive at night; clear weather; fresh NW. wind; station west of high; brilliant aurora on night of 20th; heavy rains in NW. (northwestern dist.) and South Atlantic stations.
June 1	Variable positive to negative all day; clear weather; brisk NW. wind; station west of low; rain in early morning; rain at Ohio and Canadian lower lake stations during the day.
June 4	Variable positive to negative 10 a. m. to 1 p. m.; clear weather; fresh NW. wind; station east of high; clear at surrounding stations all day.
June 7	Variable positive to negative all day; cloudy weather; fresh NW. wind; station east of high; rained 10 miles south of station during a. m.; also at Oswego and Rochester, N. Y., and Erie, Pa.
June 12	Variable positive to negative 9 to 10 a. m.; fair weather; fresh N. wind; station north of a high; rain at Oswego and Rochester during early morning; fair during rest of day.
June 30	Variable positive to negative 9 to 11 a. m.; clear weather; fresh NW. wind; station west of a high; rain fell at nearly all lower lake stations during the evening.
July 11	Negative 1 to 3 p. m.; clear to cloudy weather; fresh SW. wind; station south of low; rain fell at nearly all lower lake stations during the whole day.
July 15	Variable positive to negative 11 a. m. and 1 p. m.; hazy weather; fresh NW. wind; station neither in a high nor a low; clear at all surrounding stations.
July 25	Variable positive to negative 9 to 11 a. m.; fair weather; fresh NW. wind; station west of a high; rain fell at Montreal, Canada, and in upper lake regions during day and at all lower lake stations during night.
Aug. 2	Variable positive to negative 9 a. m.; clear weather; gentle east wind; station neither in a high nor a low; fair to cloudy weather at surrounding stations; rain fell at Pittsburg, Pa., and at Ohio lake stations.
Aug. 5	Negative at 3 p. m.; fair and cloudy weather; light NW. wind; station south of low; fair to cloudy weather at surrounding stations during the day; rain fell at Albany, New York City, and many Atlantic coast stations after 8 p. m.
Aug. 14	Negative at 11 a. m.; clear weather; light NW. wind; station neither in high nor low; rain fell at Rochester and Oswego, N. Y., and Canadian lower lake stations during night.
Aug. 25	Negative at 9 a. m.; clear weather; fresh W. wind; rain fell at Kingston and Montreal, Canada, during the evening.

TABLE W.—*Negative potentials without precipitation, Baltimore, Md.*, 1885, 1886, *and* 1887.

Date.	Remarks.
1885.	
Jan. 10	Variable positive with occasional negative from 10 p. m. of 9th to 12 m. of 10th; clear; NW. brisk winds.
Jan. 21	No record in a. m.; weak positive and negative from 12 m. to 8 p. m., then positive; clear; cold wave and gale coming.
Jan. 29	Positive, except negative at 10 p. m.; cold; clear; rising temperature.
Feb. 2	Slight negative at noon and at 8 p. m.; positive at other times; brisk NW. winds; cloudy.
Feb. 3	Negative from 9 to 11 a. m.; variable positive at other times; fresh E. to NE. winds; fair; ice in harbor.
Feb. 8	Slight negative at 7 a. m.; positive at other times; cloudy; lt. NE. winds.
Feb. 11	Negative from midnight to 11 a. m., then positive; clear; cold wave; brisk NW. winds.
Feb. 19	Variable positive all day, except positive and negative from 9 to 11 p. m.; clear; cold NW. winds.
Feb. 20	Positive with occasional negative; brisk NW. winds; cold and clear.
Mar. 3	Variable positive in p. m. to 8:30 p. m., then positive and negative until 3 a. m. of 4th; lt. S. winds; cloudy.
Mar. 10	Positive until 8 p. m.; negative 8 to 8:30 p. m., then variable positive; clear and warm; lt. variable winds, shifting to brisk NW. winds in the late p. m.
Mar. 16	Positive, with occasional negative, all day; fair; cold wave coming; winds changing to brisk NW.
Mar. 18	Variable positive, with occasional negative, all day; clear; cold wave; fresh NW. winds.
Mar. 21	Negative and positive from 10 p. m. of 20th to 11 p. m. of 21st; cold; fair; gale; NW. winds.
Mar. 24	Positive with negative all day; fair and cold; brisk NW. winds.
Mar. 25	Positive with slight negative all day; warmer; fair; fresh NW. winds.
Mar. 26	Same as 25th. Rain on 27th.
Mar. 30	Negative at 1:30, 6, and from 7 to 7:30 a. m.; positive at other times; fair; lt. W. winds.
Apr. 1	Negative from 7 to 9 a. m. and from 5 p. m. of 1st to 1 a. m. of 2d; positive at other times; fair; cold; lt. winds.
Apr. 21	Variable positive all day, except slight negative at 7:30 a. m.; clear; lt. S. to SE. winds.
Apr. 22	Positive, except negative 8 to 9 a. m., and positive and negative from 6 p. m. of 22d to 9 a. m. of 23d; clear; warm; lt. SE. winds.
Apr. 24	Negative and positive all day; warm; cloudy; lt. SE. winds.
Apr. 25	Positive, with occasional negative, all day; cloudy; lt. NE. to SE. winds.
Apr. 29	Variable negative from 7 to 11 a. m.; variable positive at other times; clear and cool; gale; NW. winds, reaching a maximum at 7:30 a. m.
May 8	Slight negative at 7 and 9 a. m.; positive at other times; cloudy; threatening; NE to NW. winds.
May 9	Variable positive all day, except negative from 6 to 7 a. m. and from 4:30 to 6:30 p. m.; cloudy; fresh SE. veering to NW. winds.
May 15	Steady positive in a. m.; variable positive with slight negative in p. m.; clear; brisk NE. to NW. winds.
May 16	Positive and negative in a. m.; no record in p. m.; clear; warm; fresh NE. to SE. winds.
May 19	Positive and negative in a. m.; positive in p. m.; warm; fair; SE. to S. winds.
June 2	Positive, with slight negative at midnight and at 7 p. m.; fair; brisk NW. winds.
June 11	Variable positive all day, except slight negative at 12 m.; clear; warm SE. to SW. winds.
June 13	Zero to slight negative steady from noon 13th to noon 14th; record not good; brisk SE. winds on 13th; brisk NW. winds on 14th; fair.
June 20	Variable positive all day, except slight negative from 6 to 6:30 a. m.; fair; lt. W. to fresh SE. winds.
June 24	Low steady negative potential from 9 a. m. to 2 p. m.; positive at other times; fair; lt. variable winds.
July 20	Positive low and steady, except slight negative from 5:30 to 6:30 p. m.; fair; very warm.
Aug. 15	Variable positive all day, except slight negative at 6 p. m.; cool; fair; fresh N. winds.
Aug. 17	Positive, except slight negative at 7 a. m.; cloudy and warm; E. to S. winds.
Sept. 16	Variable positive all day, except slight negative from 4 to 5 p. m.; clear; fresh NW. winds.
Sept. 18	Variable positive, with slight negative at 7 a. m.; clear; fresh S. winds
Sept. 25	Negative from 8 to 8:30 a. m. and from 8 to 9 p. m.; positive at other times; clear; lt. variable winds.
Sept. 26	Negative from 8 to 9 a. m.; positive rest of the time; cloudy; dense haze in a. m.; clear in p. m.; lt. variable winds.
Sept. 28	Slight negative at midnight, 9 a. m., and 6 to 7 p. m.; positive at other times.
Oct. 16	Variable positive, except slight negative at 8, 10 p. m., midnight, and also 7 p. m. of 17th; fair weather; lt. variable winds.
Oct. 18	Negative from 4 to 5 a. m. and from 7 to 8 a. m.; positive at other times; dense fog in a. m., followed by clear weather.
Oct. 26	Variable positive, except slight negative at 8 p. m. of 25th and from 8 to 9 a. m. of 26th; clear; lt. N. winds.
Oct. 27	Variable positive and negative from midnight to 10 a. m.; positive at other times; dense fog, clearing away by noon.
Oct. 28	Negative and positive from 2 to 8 a. m.; positive at other times; dense fog until 10 a. m.
Dec. 18	Negative from 6 to 9 a. m. and at 11 p. m.; positive at other times; warm; fair; lt. variable winds.
Dec. 24	Variable positive, with occasional negative, all day; fair; NW. winds.
Dec. 26	Variable positive and negative from 8 a. m. of 26th to 7 a. m. of 27th; clear; brisk NW. winds.

TABLE W.—*Negative potentials without precipitation, Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Remarks.
1885.	
Dec. 30	Negative from 7 to 9 a. m.; variable positive at other times; warmer, fair weather; SE. winds.
1886.	
Jan. 2	Variable positive and negative from midnight to 2 a. m. and at 7 a. m.; variable positive the rest of the time; clear weather; lt. winds, mostly easterly.
Jan. 3	Variable positive all day, except negative from 4:30 to 5 a. m.; cloudy weather; falling barometer; SE. to NE. winds.
Feb. 19	Negative at 5 a. m.; variable positive and negative from 2 to 8 p. m.; positive rest of the time; rapidly falling barometer; fair weather; S. winds during the day, changing to brisk, and to gale NW. winds at sunset; cold wave approaching.
Feb. 20	Variable positive and negative all day; fair and cold; NW. gale.
Feb. 22	Negative from 1 to 1:30 a. m. and from 5 to 5:30 p. m.; positive rest of the time; clear and warmer; NW., backing to S. winds.
Mar. 1	Variable positive from midnight to 5 p. m.; variable negative, with an occasional positive, from then until midnight; clear and cold; NW. brisk to gale winds.
Mar. 2	No record in a. m.; variable positive and negative in p. m.; clear and cold; NW. brisk to gale winds.
Mar. 3	Variable positive and negative all day; clear; brisk to gale NW. winds.
Mar. 10	Negative from 4:15 to 4:30 a. m.; variable positive rest of the day; fair weather; fresh NE. winds.
Mar. 15	Negative from 7 to 8 a. m. and at 3 and 6 p. m.; variable positive rest of the time; clear, with a warm wave; max. tempt., 71°; SW. winds.
Mar. 16	Negative at 6:30 a. m.; variable positive and negative from 11 a. m. to 4 p. m.; positive rest of the time; fresh SW. winds, veering at noon to br. NW. winds; clear and warm.
Mar. 17	Variable positive all day, except negative from 10 p. m. to midnight; clear and cooler; fr. NW. winds; lunar corona from 7 p. m. to midnight.
Mar. 23	Variable positive and negative from 12 m. to 4 p. m.; variable positive in a. m. and p. m.; cloudy; brisk NW. winds.
Mar. 25	Variable positive and negative all day; warmer weather; smoky; lt. SW. winds.
Apr. 1	Weak variable positive and negative from 6 a. m. to 7 p. m.; positive at other times; clear; brisk SW. winds.
Apr. 2	Weak variable positive and negative all day; fair, followed by cloudy weather; brisk SW. winds.
Apr. 9	Variable positive all day, except negative from 9 to 9:15 p. m.; clear weather; rising temperature.
Apr. 21	Variable strong positive all day, except negative from 8:30 to 11 p. m.; cloudy and threatening followed by clear weather.
Apr. 22	Variable positive all day, except slight negative at 11 a. m.; clear and warm, with variable winds.
Apr. 23	Variable weak positive and negative all day; clear and warm; falling barometer; SW. winds.
Apr. 26	Variable positive and negative all day; cloudy and threatening; E. winds.
Apr. 27	Variable positive and negative all day; cool and cloudy; fresh SE. to NE. winds.
Apr. 29	Variable positive, with an occasional negative; fair and cool; fresh E. winds.
May 2	Variable positive in p. m., with occasional negative; clear; SE. winds.
July 3	Variable positive all day, except a slight negative at 4 p. m.; fair weather; northerly winds.
July 5	Steady positive all day, except slight negative at 9:15 p. m.; clear and warm; NW. winds.
July 8	Weak positive and negative all day; clear followed by cloudy weather; N. to NE. winds.
July 9	Weak variable positive, with negative from 7 to 8 a. m.; cloudy weather; SE. winds.
July 12	Variable positive all day, except slight negative at 4 a. m., 5, and 10 p. m.; clear; NE. to SE. winds.
July 23	Weak variable positive all day, with negative from 6 to 7 a. m. and from 5 to 8 p. m.; cloudy followed by clear weather; N. winds.
Aug. 10	Positive all day, with a slight negative at 7 a. m.; cloudy; falling barometer; southerly winds.
Aug. 21	Variable positive all day, except slight negative at 6 p. m.; fair and cool; E. winds.
Sept. 17	Variable positive all day, except negative from 7 to 8 p. m.; heat lightning at 7:30 p. m.
Sept. 26	Steady positive all day, except negative from 1 to 2 p. m.; slightly warmer, cloudy weather; S. to SW. gale.
Sept. 30	Positive, except slight negative, at 1 and 6 p. m.; clear and cool; SE. to NE. wind.
Oct. 7	Clear and cool; lt. NE. winds; positive, except occasional negative, at 2 and 6 p. m.
Oct. 8	Similar to 7th.
Oct. 16	Variable positive and negative from 6 a. m. to noon; positive rest of the time; fair, with cold wave.
Oct.	Variable positive all day, except occasional negative from 7 to 10 p. m.; clear, with warm wave.
Oct. 19	Variable positive all day, with negative from 5 to 8 a. m.; cloudy, followed by fair weather.
Oct. 23	Slight negative at 6 p. m.; clear; variable winds.
Oct. 25	Slight negative at 7 a. m.; fair; variable winds.
Nov. 20	Variable positive all day, except negative from 6 to 6:30 a. m.; cold; fair; SW. winds.
Dec. 2	Variable positive and negative from 12 m. to 4 p. m.; clear; cold NW. gale.
Dec. 3	Variable positive and negative from 12 m. to 3 p. m.; cold NW. gale; collector seems to have been frozen in a. m. of 2d and 3d.
Dec. 10	Variable positive all day, except negative from 9 to 10 p. m.; clear; lt. variable winds.
Dec. 21	Negative from midnight to 2 a. m.; positive rest of the day; clear; lt. variable winds.

TABLE W.—*Negative potentials without precipitation, Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

Date.	Remarks.
1887.	
Jan. 10	Variable positive and negative from 11 a. m. to 4 p. m.; snow ended early a. m., followed by fair weather; NW. gale.
Jan. 21	Negative from 7 to 8:30 p. m.; positive at other times; cloudy and mild; brisk SW. winds.
Jan. 22	Negative from 6:30 to 8:30 p. m.; positive at other times; mild and fair.
Jan. 31	Slight negative at 9 a. m; positive all day; clear; lt. SE. winds; lunar corona 7 to 8 p. m.
Feb. 16	Negative from 6:30 to 8 a. m. and from 5:30 to 5:45 p. m.; positive rest of the time; dense fog in a. m., followed by threatening, cloudy weather.
Mar. 2	Variable positive, with occasional negative, all day; warmer, fair weather; SE. to NE. winds.
Mar. 12	Negative from 7 to 11 a. m.; positive at other times; clear; brisk NW. winds.
Mar. 14	Variable positive, with negative from 4:30 to 5:30 p. m.; cloudy, with brisk NW. winds.
Mar. 16	Variable positive and negative from 8 a. m to 5 p. m.; fair, with brisk NW. winds.
Mar. 25	Negative from 10 a. m. to 12 m.; positive rest of the day; fair; severe NW. gale.
Mar. 29	Variable positive and negative all day; fair; brisk to high NW. winds.
Apr. 7	Variable positive and negative all day.; cloudy; warmer; easterly winds.
Apr. 10	Positive all day, except negative at 1 and 3 a. m.; clear and warm wave.
Apr. 13	Slight negative in early a. m.; then positive; fair; easterly winds.
Apr. 21	Slight negative at 1:30 a. m.; then positive; clear; warmer; southerly winds.
May 3	Positive, with occasional negative, all day; fair, with S. to SE. winds.
May 4	Positive, with occasional negative, all day; fair, with SE. winds; rain a. m., 5th.
May 13	Variable positive and negative all day; clear and cool; E. winds.
May 16	Positive and negative all day; falling barometer; SE. winds; fair.
May 17	Positive and negative all day; falling barometer; northerly changing to SE. winds; warm and hazy.
May 18	Positive, with occasional negative; cloudy; NE. to SE. winds.
May 19	Positive, with occasional negative; clear; NE. to SE. winds.
June 11	Variable positive and negative from 9 a. m. to 6 p. m.; positive rest of the time; clear; gale; E. winds.
June 14	Positive and negative in a. m.; positive in p. m.; clear; NE. to SE. winds.
June 17	Weak positive and negative all day; warm; max. tempt. 93°; fair; W. winds; silent lightning at night.
July 14	Variable positive and negative from 4 p. m. to midnight; clear and warm; lt. N. winds.
July 15	Variable positive all day, with negative from 6 to 7 p. m.; clear; lt. SE. to NE. winds.
July 28	Positive all day, except sudden and strong negative from 3:30 to 5:30 p. m.; dense fog in a. m.; clear in p. m.; lt. SE. winds.

TABLE W.—*Negative potentials without precipitation, Baltimore, Md.*, 1885, 1886, *and* 1887—Continued.

SUMMARY OF NEGATIVE WITHOUT PRECIPITATION.

Month.	Winds brisk to gale, NW.		Winds light to fresh, NE. to SE. (Sea breeze.)		Winds light to fresh, S.		No marked condition.	Other causes.
	Cloudy.	Clear.	Cloudy.	Clear.	Cloudy.	Clear.		
1885.								
January	0	2	0	0	0	0	1	0
February	1	3	1	1	0	0	0	0
March	0	8	0	0	1	0	1	0
April	0	1	2	2	0	0	1	0
May	0	1	2	1	1	0	0	0
June	1	1	1	2	0	0	0	0
July	0	1	0	0	0	0	0	0
August	0	1	1	0	0	0	0	0
September	0	1	0	0	0	1	3	0
October	0	0	0	0	0	0	2	*3
November	0	0	0	0	0	0	0	0
December	0	3	1	0	0	0	0	0
1886.								
January	0	0	0	2	0	0	0	0
February	0	3	0	0	0	0	0	0
March	1	5	0	1	1	1	0	0
April	0	0	3	0	2	0	3	0
May	0	0	0	1	0	0	0	0
June	0	0	0	0	0	0	0	0
July	0	1	2	1	0	0	2	0
August	0	0	0	1	1	0	0	0
September	0	0	0	1	1	0	0	†1
October	0	0	0	2	0	0	5	0
November	0	0	0	0	0	1	0	0
December	0	2	0	0	0	0	2	0
1887.								
January	2	0	0	1	0	0	1	0
February	0	0	0	0	0	0	0	‡1
March	1	4	0	1	0	0	0	0
April	0	0	1	1	0	1	1	0
May	0	0	5	2	0	0	0	0
June	0	0	0	2	0	0	0	†1
July	0	0	0	1	0	0	1	‡1
Total (126)	6	37	19	23	7	4	23	7
Rain next day (26)	1	8	3	4	2	1	4	3

* Dense fog. † Lightning. ‡ Fog.

TABLE X.—*Negative potentials without precipitation, Washington, D. C., October, 1887, to August, 1888.*

Date.	Remarks.
1887.	
Nov. 8	Potential variable positive to negative at 11 a. m. and 1 p. m.; cloudy during a. m.; hazy during p. m.; light SW. wind; station in anticyclonic area; light rain at Norfolk, Va., during the afternoon about 3 p. m.
Nov. 9	Potential negative at 1 p. m.; cloudy all day; light NE. wind; station east of a low; heavy rain in Ohio Valley during the evening; rain at this station on the 10th.
1888.	
Jan. 26	Potential negative 9 to 11 a. m. and 1 to 3 p. m.; fair weather; brisk NW. wind; snow at Pittsburg, Pa., during the day; at this station at 8 a. m. on 27th.
Mar. 19	Potential variable positive to negative at 9 a. m.; clear weather; light S. wind; rain at 5 a. m. on 20th at this station; rain all day on 19th in Ohio Valley.
Apr. 2	Potential negative at 1 p. m.; fair weather; fresh NW. wind; station east of a high; generally clear weather at neighboring stations; light rain in Tennessee.
Apr. 7	Potential variable from positive to negative at 3 p. m.; cloudy weather; brisk W. wind; station south of a high; fair weather at surrounding stations.
Apr. 20	Potential negative at 11 a. m. and 1 and 3 p. m.; fair weather; brisk NW. wind; station east of a high; rain in lake regions and at Philadelphia, Atlantic City, and Norfolk.
Apr. 27	Potential negative at 5 p. m.; clear weather, with light haze; light NE. wind; station neither in a high nor a low; clear throughout eastern part of the country; rains throughout the western part.
Apr. 28	Potential variable positive to negative at 5 p. m.; clear weather, with light haze; light SE. wind; station neither in a high nor a low; clear in eastern part of country; rain and snow throughout the West.
Apr. 30	Potential variable positive to negative at 9 and 11 a. m.; dense haze; calm in a. m.; light S. wind in p. m.; station within a low; quite heavy rain and snow throughout lower lakes and Ohio Valley; light rain at Pittsburg, Pa., about 4 p. m.
May 17	Potential variable positive to negative at 1 p. m.; clear weather; light NW. wind; rain throughout the Northwest, Mississippi Valley, lake regions, and Ohio Valley; light rain at Pittsburg, Pa.
May 21	Potential variable positive to negative 1 p. m.; fair weather; light SE. wind; station north of a low; rain fell at all stations in Virginia, North Carolina, and Tennessee.
June 11	Potential negative at 3 p. m.; variable positive to negative at 5 p. m.; clear weather; brisk NW. wind; rain fell at Pittsburg and Philadelphia, Pa., Atlantic City, N. J., and Norfolk, Va.
June 12	Potential variable positive to negative from 11 a. m. to 5 p. m.; clear weather; light easterly wind; fair weather at surrounding stations; rain in Gulf States and throughout the West.
July 2	Potential variable positive to negative at 3 p. m.; clear weather; light E. wind; generally clear weather at surrounding stations.
July 16	Potential variable positive to negative 1 to 5 p. m.; clear weather, with light haze; light easterly wind; rain fell throughout South Atlantic and Gulf States during the night.
July 17	Potential variable positive to negative at 11 a. m. and 3 p. m.; clear weather; light SE. wind; station in anticyclonic area; rain fell in Ohio Valley and at Pittsburg during day and night.
July 18	Potential variable positive to negative at 1 p. m.; clear weather; brisk SE. wind; station south of low; rain fell at Pittsburg and in Ohio Valley during the day, and at Baltimore during night.
July 27	Potential variable positive to negative at 3 p. m.; cloudy weather; fresh NE. wind; station in anticyclonic area; rain fell at Norfolk, Baltimore, Atlantic City, Philadelphia, and Ohio Valley during the day.
July 28	Potential variable positive to negative at 11 a. m.; fair weather; fresh NE. wind; station neither in high nor low; rain fell at Lynchburg, Va., and vicinity during the evening.
Aug. 30	Potential variable positive to negative at 9 a. m.; clear weather; light S. wind; station neither in high nor low; rain fell at Lynchburg, Va., and Upper Ohio Valley during the night.

TABLE Y.—*Negative potentials without precipitation, Boston, Mass., December*, 1887, *to August*, 1888.

Date.	Remarks.
1887.	
Dec. 29	Potential negative at 11 a.m., 3 and 5 p. m.; clear weather all day; brisk NW. wind; lt. snow fell at Northfield, Vt., Albany, and New York City, N. Y., during the day.
1888.	
Jan. 3	Potential negative at 1, 3, and 5 p.m.; cloudy weather; gentle NW. wind; station neither in a high nor a low; lt. snow fell at Northfield, Vt., all day.
Jan. 11	Potential negative at 11 a. m., 1 and 3 p. m.; clear weather; fresh W. wind; station east of a high; lt. snow at Yarmouth, N. S., all day; clear at nearer stations.
Jan. 18	Potential negative at 11 a. m.; cloudy weather; light NW. wind; station west of a low; snow at Northfield, Vt., Portland, Me., and Nantucket, Mass., all day.
Jan. 24	Potential negative at 9 and 11 a. m.; clear weather; brisk NW. wind; station east of high; snow at Northfield, Vt., and in Nova Scotia during the day.
Feb. 28	Potential negative at all five observations; clear weather; brisk NW. wind; station east of high; snow in Nova Scotia all day.
Mar. 6	Potential negative at 11 a. m.; cloudy in a. m.; clear during p. m.; brisk NW. wind; station west of a low; rain fell at Portland, Me., about noon.
Mar. 7	Potential negative at 9, 11 a. m., and 3 p. m.; clear weather; brisk W. wind; station neither in a high nor a low; snow in northern New York and at Eastport, Me., all day.
Mar. 8	Potential negative at 9, 11 a. m., 1 and 3 p. m.; cloudy weather; high E. wind; station south of low; snow fell at Eastport, Me., and northern New York all day.
Mar. 23	Potential negative at all five observations; clear weather; high SW. wind; station west of low; rain fell at Eastport and Portland, Me., Albany, N. Y., and New London, Conn., during the day.
Mar. 24	Potential negative at all five observations; perfectly clear weather; brisk SW. wind; station east of a high; lt. snow fell in northern New York, Quebec, Canada, and in Nova Scotia during the day.
Mar. 31	Potential negative at 11 a. m., 1, 3, and 5 p. m.; fair weather; brisk to high W. wind; station neither in a high nor a low; snow fell at Montreal, Canada, Northfield, Vt., and Eastport, Me., all day.
Apr. 4	Potential negative for a few minutes about 11 a. m.; clear weather; brisk W. wind; station within a high; dust clouds were raised by wind in vicinity of station about 11 a. m.; clear all day at surrounding stations
Apr. 7	Potential negative at all five observations; clear weather; high W. wind; station neither in a high nor a low; fair weather at surrounding stations.
Apr. 9	Potential negative at 3 p. m.; clear weather (perfectly); fresh NW. wind; station within a high; dust clouds raised by wind about 3 p. m.; clear at neighboring stations; rain throughout Gulf States, Ohio Valley, and lake regions.
Apr. 24	Potential zero at 11 a. m.; negative at 1 p. m.; cloudy weather; brisk NW. wind; station east of a high; rain at Northfield, Vt., about noon; fair at stations south and cloudy at stations north of Boston.
Apr. 25	Potential negative at 11 a. m.; clear weather; fresh NW. wind; station within a high; negative reading without a visible cloud and no wind to raise dust; no other negative values seen during day; generally clear weather throughout eastern part of country.
May 3	Potential negative at 1 p. m.; clear weather; fresh NW. wind; station east of a low; no dust recorded; clear weather at neighboring stations; rain in upper lakes; rain in this district on morning of 4th.
May 8	Potential negative at 3 and 5 p. m.; cloudy weather; brisk SW. wind; station east of a low; dust clouds during p. m.; rain all day throughout the North Atlantic districts and lower lakes.
June 9	Potential negative at 5 p. m.; clear weather; fresh S. wind; station east of a low; rain in St. Lawrence Valley during the day; throughout New England on 10th.
June 13	Potential negative at 5 p. m.; cloudy weather; fresh SW. wind; station north of a high; rain fell during night at Albany, N. Y., Northfield, Vt., and Portland, Me.
June 27	Potential negative at 1 and 3 p. m.; clear weather; brisk NW. wind; station west of a low; rain fell at Block Island, R. I., New York City, and southern stations during the evening; dust clouds from 1 to 3 p. m.
July 12	Potential negative at all five observations; clear weather; high W. wind; station south of a low; light haze all day, with dust clouds; rain fell at Eastport, Me., Northfield, Vt., and in New York City during the day.
Aug. 29	Potential negative at 3 p. m.; clear weather; brisk W. wind; station south of a low; fair weather at neighboring stations. There is every reason to think that the negative potentials were caused by dust. There was a high NW. wind on 28th, the ground was thoroughly dried and the brisk W. winds to-day no doubt raised dust clouds. The negative potential occurred simultaneously with the greatest force of the wind.

NATIONAL ACADEMY OF SCIENCES.

VOL. V.

FOURTH MEMOIR.

THE EMBRYOLOGY AND METAMORPHOSIS OF THE MACROURA.

THE

EMBRYOLOGY AND METAMORPHOSIS

OF THE

MACROURA.

BY

W. K. BROOKS,

PROFESSOR OF ANIMAL MORPHOLOGY IN THE JOHNS HOPKINS UNIVERSITY,

AND

F. H. HERRICK,

PROFESSOR OF BIOLOGY IN ADELBERT COLLEGE,

LATE FELLOW IN THE JOHNS HOPKINS UNIVERSITY.

WITH FIFTY-SEVEN PLATES.

S. Mis. 94——21

CONTENTS.

I. Introduction.
II. The life history of Stenopus hispidus.
Section 1. Natural history of Stenopus.
Section 2. Segmentation and the early stages.
Section 3. Metamorphosis of the larva.
Section 4. The adult.
Remarks.
List of species.
Literature of Stenopus.
III. The habits and metamorphosis of Gonodactylus chiragra.
Section 1. The structure and habits of the adult.
Section 2. Metamorphosis.
IV. The metamorphosis of Alpheus.
Section 1. The metamorphosis of Alpheus minos.
Section 2. The metamorphosis of Alpheus heterochelis in the Bahama Islands.
Section 3. The metamorphosis of Alpheus heterochelis at Beaufort, North Carolina.
Section 4. The metamorphosis of Alpheus heterochelis at Key West, Florida.
Section 5. The larval development of Alpheus saulcyi.
V. Alpheus: A study in the development of the Crustacea.
Introduction.
Methods.
PART FIRST.
Section 1. The habits and color variations of Alpheus.
PART FIRST—Continued.
Section 2. Variations in Alpheus heterochelis.
Section 3. The abbreviated development of Alpheus and its relation to the environment.
Section 4. The adult.
Section 5. Variations from the specific type.
Section 6. Measurements.
Section 7. The causes and significance of variation in Alpheus saulcyi.
PART SECOND.
Development of Alpheus.
Section 1. Structure of the larva of Alpheus saulcyi.
Section 2. The origin of ovarian eggs in Alpheus, Homarus, and Palinurus.
Section 3. Segmentation in Alpheus minos.
Section 4. The embryology of Alpheus. Stages 1–13.
Section 5. Notes on the segmentation of Crustacea.
Section 6. Cell degeneration.
Section 7. The origin and history of wandering cells in Alpheus.
Section 8. The development of the nervous system.
Section 9. The eyes.
Section 10. Summary.
Section 11. References.
Explanation of figures (accompanying each plate).

[With fifty-seven plates.]

CHAPTER I.

INTRODUCTION.

By W. K. Brooks.

No great group of animals is more favorable than the Crustacea for the study of the history and significance and origin of larval forms, for these animals possess a number of peculiarities which serve to render the problem of their life history both unusually interesting and significant, and at the same time unusually intelligible; nor are these peculiar features exhibited, to the same degree, by any other great group of animals.

The body of an arthropod is completely covered, down to the tip of each microscopic hair, by a continuous shell of excreted matter, and as this chitinous shell is not cellular it can not grow by the interpolation of new cells, nor can it, like the excreted shell of a mollusk grow by the deposition of new matter around its edges, for there are no such growing edges, except in a few exceptional cases, such as the barnacles. Once formed and hardened the cuticle of an arthropod admits no increase in size, and as soon as it is outgrown it must be discarded and replaced by a new and larger one. The new shell is gradually excreted, in a soft condition, under the old one, and as soon as this is thrown off the new one quickly becomes fully distended and solid. As a result, from the very nature of the chitinous shell and the method of renewal which its structure entails, the growth of an arthropod, from infancy to the adult condition, takes place by a series of well marked steps or stages, each one characterized by the formation of a new cuticle and by a sudden increase in size.

In most arthropods the newly-born young are very different in structure from the adults, and growth is accompanied by metamorphosis. As the changes of structure are necessarily confined to the moulting periods, the stages of growth coincide with the stages of change in organization, and there is none of the indefiniteness which often characterizes the different larval stages of animals with a more continuous metamorphosis. On the contrary the nature of each change is as sharply defined and as characteristic as the structure of the adult itself. As the moulting period is frequently a time of inactivity the animal may then undergo profound changes without inconvenience, and the successive steps in the metamorphosis of an arthropod are not only well marked, but often very profound as well.

In these features all the other arthropods are like the Crustacea, but another consideration, the fact that, with few exceptions, the higher Crustacea are marine, renders the problem of their life history much more intelligible than that of any other class of animals.

So far as the ontogenetic history of the metamorphosis of a larva is a recapitulation of ancestral stages in the evolution of the species its retention at the present day must depend to a great degree upon the persistency of those external conditions to which the larval stages were originally adapted.

This is true at least of all free larvæ, which have their own battle to fight and their own living to get, and while a larva inside an egg or within a brood pouch may possibly recapitulate obsolete ancestral stages, the survival of a free larva depends upon its adaptation to its present environment.

As compared with the ocean the inorganic environment of terrestrial or fresh-water animals is extremely variable, and changes in climate, elevation, and continental configuration are accompanied by corresponding changes in enemies, competitors, and food, so that the conditions which

surround a modern terrestrial larva must, in nearly every case, be very different from those under which the remote ancestors of the species passed their life, but while this is also true, to some degree, of marine animals their inorganic environment is comparatively stable, and the persistence of so many ancient marine types shows that the changes in the organic surroundings of marine animals take place much more slowly than corresponding changes on land.

This fact, joined to the definite character of the changes which make up the life history of a marine crustacean, renders these animals of exceptional value for the study of the laws of larval development, and for the analysis of the effect of secondary adaptations, as distinguished from the influence of ancestry; for while Claus has clearly proved that adaptive larval forms are much more common among the Decapods than had been supposed, his writings and those of Fritz Muller show that no other group of the animal kingdom presents an equal diversity of orders, families, genera, and species in which the relation between ontogeny and phylogeny is so well displayed, but, while proving this so clearly, Claus' well known monograph also shows with equal clearness that this ancestral history is by no means unmodified, and that the true significance of the larval history of the higher Crustacea can be understood only after careful and minute and exhaustive comparison and analysis.

Greatly impressed by this fact, I began nearly ten years ago to improve the opportunities that were offered by the marine laboratory of the Johns Hopkins University, for obtaining more complete and detailed knowledge of the larval stages of a number of Macroura, and this work has been prosecuted at every opportunity up to the present time. Some of my results have been published in my monograph on Lucifer, in the Phil. Trans. Royal Soc. for 1882, and others are incorporated in my report on the Stomatopoda collected by H. M. S. *Challenger*.

This memoir contains the life histories of a number of additional species based in part upon my own studies at Beaufort, North Carolina, and at Green Turtle Key and New Providence in the Bahama Islands, but chiefly upon the researches which one of my students, Mr. F. H. Herrick, has carried on under my general supervision. In 1886 he undertook, at my suggestion, the study of the embryology and metamorphosis of the Macroura, and devoted three years to this subject under my direction, and the results which follow are almost entirely due to his zeal and energy. He has completed the study of several subjects upon which I had previously made a beginning, so that my own unfinished notes have been incorporated with his researches, and our respective shares in the work are as follows: The chapter on Gonodactylus is entirely based upon my own researches; the chapter entitled "*Alpheus*, a study in the development of the Crustacea," is entirely the work of Mr. Herrick; the one on the metamorphosis of Alpheus is based upon our combined studies, and that upon Stenopus is almost entirely the work of Mr. Herrick, as my own contributions to this life history are of minor value except so far as they supplement his work.

I shall now give a brief outline or summary of the chief results which are described in detail in each chapter.

THE LIFE HISTORY OF STENOPUS HISPIDUS.

During the six seasons which I spent at Beaufort, North Carolina, I captured in the tow-net, at different times, some six or seven specimens of a remarkable pelagic crustacean larva, all of them well-advanced and in nearly the same stage of development.

Nothing was learned of the earlier larval life nor of the adult form of the animal, although enough was made out to show that it is one of the few Macroura which, like Peneus and the Sergestidæ, have retained the primitive or ancestral metamorphosis, and that its secondary modifications are very slight as compared with those of ordinary macrouran larvæ, and also that the Beaufort larvæ are new to science. (See Pls. IX and X.)

These larvæ have the full number of adult somites and appendages, and in side view they are very suggestive of the Sergestidæ. They are very much larger than ordinary pelagic larvæ and are quite different from any known forms of Macroura.

The chief locomotor organs are the last pair of thoracic legs, which are extremely slender, as long as the entire body of the larva, ending in flattened elliptical paddles, which are used as sweeps for rowing through the water. They are stretched out in front of the body near the

middle line and are then swept backwards and outwards, describing at each stroke a circle equal in diameter to about twice the length of the body. By the vigorous use of these oars the larva skims rapidly through the water, and its movements are not unlike those of a Gerris upon the surface of a fresh-water pond.

Notwithstanding the importance of a complete knowledge of the life history of the animal to which this sergestid-like larva belongs, I was unable to complete the study at Beaufort, although I made careful drawings of two stages and filed them away for future use.

Immediately upon our arrival at Green Turtle Key, in the Bahama Islands, early in June, 1886, our attention was at once attracted to a small, graceful, brilliantly colored prawn which was found in abundance among the coral. (See Pl. v.) It proved to be *Stenopus hispidus*, a species which is chiefly known to naturalists through specimens from the Indian and South Pacific oceans. It has been recorded as occurring in the tropical Atlantic, but our knowledge of the adult has been very scanty and imperfect, and nothing whatever has been known regarding its life history until Mr. Herrick devoted himself to its thorough investigation.

It is an active, timid animal, and is one of the most brilliantly colored of the crustacea. As it is also one of the most widely distributed, it is noteworthy that while its color markings are so prominent and conspicuous they are extremely well fixed and constant; so much so that the specimens from the Indian Ocean and the South Pacific agree with those from the West Indies down to the most minute markings.

The adults are found in pairs, a male and a female swimming together side by side and exhibiting evidence of strong conjugal attachment to each other.

The most noteworthy fact in its history is its world-wide distribution, and the question whether this can be a result of any peculiarity in its structure or habits at once suggests itself.

We should expect, on general principles, to find the least specialized species the most widely diffused; and one which holds its ground in so many parts of the world, and without any change of structure finds a safe and congenial home in seas so widely separated, might be expected to be of indefinite or slightly specialized habits, but this is not the case. In structure, in habits, in color, and in external appearance, and also in its metamorphosis, Stenopus is one of the most highly specialized of the crustacea; and it owes its ability to survive in many seas to the accuracy and delicacy of its adjustment to a narrow range of conditions, rather than to indefinite and vague adaptation to many conditions.

Its antennæ are unusually long and slender, and the acuteness of its senses, together with its very remarkable alertness; the quickness with which it perceives danger, and the rapidity with which it escapes; have undoubtedly aided it in holding its own wherever it has gained a foothold in a suitable locality, and no crustacean, with the exception, possibly, of Gonodactylus chiagra, is better adapted for life in a coral reef.

It is well protected from enemies by a thorny armor of hooked spines, which cover all the upper surface of its body and limbs, and as all the hooks point forward the attempt of an enemy to swallow a Stenopus must be difficult and painful.

These facts no doubt account for its survival, and the length of its pelagic larval life is beyond question an aid to its wide dispersal and to the discovery of new homes.

While we cannot state that the adult will not at some time be found upon the Atlantic coast of our Southern States, there is no evidence that this is the case, and the larvæ which were obtained at Beaufort, North Carolina, were undoubtedly hatched from eggs which were carried upon the abdominal appendages of parents in the West Indies or on the Florida Keys; and these larvæ had therefore wandered more than six hundred miles from their birthplace. The species might therefore be diffused through a chain of coral islands six hundred miles apart, from a single starting point, in a very small number of generations.

The eggs, which are very small, are laid at night, and the segmentation, which Professor Herrick has thoroughly studied by sections, is entirely confined to the nuclei, the yolk remaining undivided; Stenopus therefore presents a most pronounced type of centrolycethic segmentation.

The great mass of the egg consists of a homogeneous mass of yolk granules, which takes no part in the process of segmentation and probably contains no protoplasm. This yolk is aggregated around a central nucleus, which divides, probably indirectly, into two, four, eight, sixteen

nuclei, and so on until the number is very great. As this process of division goes on the nuclei, each with an investing layer of protoplasm, gradually migrate to the surface of the yolk, and at last form a superficial investing layer around a central yolk, out of which all the protoplasm has been withdrawn.

The yolk does not divide up into typical yolk pyramids, although the outlines of the blastomeres are sharply indicated by transitory superficial furrows.

The embryonic area is soon marked out as a region where the nuclei are densely crowded, and the point of invagination is indicated by a solid ingrowth which penetrates the yolk to form the inner layers of the embryo. The subsequent stages of embryonic development were not followed in detail.

The larva hatches in the afternoon, and during the following night the parent moults and lays another brood of eggs.

At the time of its escape the larva is a Protozoea, and its later history is of great interest, since it unites features of resemblance to Lucifer, Sergestes, Peneus, and to the prawns in general, with individual peculiarities in which it differs from all of them.

At the time of hatching (Pl. VII and Pl. XI, Fig. 25) it has sessile eyes, locomotor antennæ, an enormous mandible, a deeply forked telson, a long rostrum, and a complete series of appendages as far as the first pereiopods, which are essentially like the third maxillipeds. The long hind body has no appendages and is only vaguely divided into somites.

Five or six hours after hatching it changes into a true zoea, much like that of an ordinary macrouran (Pl. VIII). The carapace becomes much enlarged; the rostrum is shortened to less than half its former length, the mandible becomes small, the forks disappear from the telson, the eyes become stalked, the antennæ are shortened like those of a zoea, and the maxillipeds become the chief locomotor organs.

As these larvæ could not be reared in captivity the later stages were studied from captive specimens, but Professor Herrick has proved that the Beaufort larvæ are either young Stenopi or else the larvæ of some closely allied species which is at present unknown.

A specimen a little older than the oldest Beaufort specimen was captured at Nassau (Pl. XII). It is in the Mastigopus stage, with greatly elongated eyes, and with antennæ which are gradually approximating to those of the adult. The third maxillipeds are now extremely long and are the largest of all the limbs, while the huge, oar-like fifth pereiopod of the preceding stage is now reduced to a rudimentary bud, and the fourth is also reduced to a two-jointed rudiment.

It thus appears that, as in the Sergestidæ, the last two pairs of "walking legs" are shed after the Mysis stage, to be again reconstructed in the Mastigopus stage. After several moults the Mastigopus larva gradually assumes the adult form, the principal changes being the shortening of the eyes and the reacquisition of the fourth and fifth pereiopods.

ALPHEUS.

The genus Alpheus includes a large number of small, brilliantly colored crayfish-like Crustacea, which are widely distributed, although all are essentially tropical. Two species range as far northward as the coast of Virginia, but the true home of the genus is the warm water between tide-marks or near the shore in coral seas, and they occur in the greatest abundance and variety in all the sounds and inlets among coral islands. They are well adapted, in structure as well as in habits, for a life among the coral, and of all the Crustacea which abound upon the coral reefs the genus Alpheus is one of the most common and most thoroughly characteristic (Pl. I, II, and IV).

Nearly every mass of sponge or algæ or of coral rock or living coral which is fished up from the bottom and broken to pieces contains specimens of one or more species of Alpheus, and pieces are often found which fairly swarm with these little animals.

A few of the species wander over the bottom, and wandering individuals of other species are found occasionally, but their true home is in the tubes of sponges and the holes and crannies in the porous coral limestone, or under the broken shells and fragments of limestone which lie upon

the bottom in shallow water. Occasionally they inhabit short, vertical burrows, which they construct for themselves in the sandy mud, but most of the species pass their life hidden in the shelter which they find upon the reef.

The most conspicuous characteristic of the genus is the great enlargement of the claws of the first pair of walking legs. Both claws are large, but one of them is enormous, and it serves as a most formidable weapon of offense and defense. In some species this large claw nearly equals the body in size, and it is usually carried stretched out in front of the body, but one species carries it folded down under the body and hidden, ready to be instantly pushed out to make a rapid thrust at any enemy.

In nearly all the species the large claw terminates in hard, powerful forceps. The claw or dactyle is provided with a plug, which fits into a well or socket in the other joint and probably serves to prevent dislocation. When the forceps are opened the dactyle is raised so that the plug just rests in the mouth of the socket. As soon as the claw is released it is suddenly and violently closed, as if by a spring, and the solid stony points striking together produce a sharp metallic report, something like the click of a water hammer, and so much like the noise of breaking glass that I have often, when awakened at night by the click of a little Alpheus less than an inch long, hastened down to the laboratory in fear that a large aquarium had been broken. In the open water the report is not so loud as it is when the animals are confined in small aquaria, but Alpheus is so abundant in all the Bahama Sounds that a constant fusilade is kept up at low water all along the shore. The animals are remarkably pugnacious and they will even attack bathers. They are known to the inhabitants of the out islands as "scorpions," and are much dreaded, although their attacks are harmless to man. The snapping propensity is exhibited both in the water and out by both sexes, and if two males or two females, either of the same or different species, are placed together in an aquarium, a most violent combat at once takes place, and quickly ends by the destruction of one or both. Some species appear to pinch with the large claw, but it is more frequently used like a saber for cutting a slashing blow. The edge of the movable joint is sharp and rounded, and the animal advances warily to the attack with the claw widely opened and stretched out to its full length. Watching its opportunity it springs suddenly upon its enemy, instantly closing its claw with a violent snap and a loud report, and cutting a vertical sweep with its sharp edge. I have often seen *Alpheus heterochelis* cut another completely in two by a single blow, and the victim is then quickly dismembered and literally torn to fragments.

The abundance of these animals in coral seas is well shown by the fact that of the twenty species which are known to inhabit the shores of the North American continent we found twelve, or more than half, upon a little reef at Dix Point, a few rods to the eastward of our laboratory at New Providence, in the Bahama Islands.

Of the thirteen species which we found in the islands several are new, and as none of them have ever been adequately described, an illustrated, systematic description of all the species is now in preparation by Mr. Herrick. The present memoir deals only with the embryology and metamorphosis of the genus. This is a new field, for nothing whatever has as yet been published upon the embryology of any species of the genus, and all our knowledge of the metamorphosis is contained in two short abstracts without illustrations on the metamorphosis of a single species, *Alpheus heterochelis*. Eggs have now been obtained from all thirteen of the Bahama species, and the first larval stages of most of them have been reared from the eggs in aquaria in the laboratory, and the metamorphosis has been traced from actual moults.

THE METAMORPHOSIS OF ALPHEUS.

One of the most remarkable results of our study of the various species of the genus Alpheus is the discovery that, while there is such a general similarity as we might expect between the larval stages of the different species, the individuals of a single species sometimes differ more from each other, as regards their metamorphosis, than the individuals of two very distinct species. This phenomenon has been observed by us and carefully studied in two species—*Alpheus heterochelis* and *Alpheus saulcyi*—and it is described in detail, with ample illustrations, in the chapter on the metamorphosis of Alpheus. In the case of the first species the difference seems to be geographical, for while all the individuals which live in the same locality pass through the same series

of larval stages, the life history of those which are found at Key West is very different from that of those which live on the coast of North Carolina, while those which we studied in the Bahama Islands present still another life history. In the case of the second species—*Alpheus saulcyi*—the difference stands in direct relation to the conditions of life. The individuals of this species inhabit the tubes and chambers of two species of sponges which are often found growing on the same reef, and the metamorphosis of those which live in one of these sponges is sometimes different from that of those which inhabit the other. In this species the adults also are different from each other, but as we found a perfect series of transitional forms there is no good reason for regarding them as specifically distinct, and in the case of the other species—*Alpheus heterochelis*—we were unable, after the most thorough and minute comparison, to find any difference whatever between adults from North Carolina and those from the Bahama Islands, although their life histories exhibit a most surprising lack of agreement. In fact, the early stages in the life of *Alpheus heterochelis* in the Bahama Islands differ much less from those of *Alpheus minor* or *Alpheus normani* than they do from those of the North Carolina *Alpheus heterochelis*, and, according to Packard, the Key West *heterochelis* presents still another life history.

In the summer of 1881 I received the American Naturalist with Packard's very brief abstract of his observations at Key West upon the development of *Alpheus heterochelis*, and read with great surprise his statement that this species has no metamorphosis, since, while still inside the egg, it has all the essential characteristics of the adult. As I had under my microscope at Beaufort on the very day when I read his account a newly hatched larva of the same species and was engaged in making drawings to illustrate the metamorphosis of which he denies the existence, and as my experience in the study of other Crustacea had taught me that all the larvæ of a species at the same age are apparently facsimiles of each other down to the smallest hair, Packard's account seemed absolutely incredible, and I hastily decided that, inasmuch as it was without illustrations and was written from notes made many years before, it involved some serious error and was unworthy of acceptance. This hasty verdict I now believe to have been unjust, since my wider acquaintance with the genus has brought to my notice other instances of equally great diversity between the larvæ of different specimens of a single species.

The phenomenon is, however, a highly remarkable one and worthy the most thorough examination, for it is a most surprising departure from one of the established laws of embryology—the law that the embryonic and larval stages of animals best exhibit their fundamental affinities and general resemblances, while their specific characteristics and individual peculiarities make their appearance later.

As in most animals the adult life is most important, the adults have a more diversified environment than the young, and the divergent modification which is continually taking place to perfect the adjustment between such organism and its conditions of life chiefly affects the adults, so that specific characters and the slight differences between varieties or races are usually confined to the adults, while the embryos and larvæ are, as a rule, more generalized.

This is true to a marked degree of those animals whose young are nursed or protected or cared for in any way by their parents, and while it is less true of those animals whose independent life begins very early, yet the same law holds with them also; and the chief scientific value of embryology lies in the fact that a knowledge of the early stages in the life of animals enables us to trace their broad affinities and to distinguish them from more recently acquired differences; for the early stages of two related forms of life share in common their more fundamental characteristics and are essentially alike, while the adults differ from each other and exhibit the divergent specializations which are of more recent acquisition.

It sometimes happens, however, that the early stages of two closely related species differ greatly. This may occur when the larvæ of the one species lead a free, independent life, while the young of the other species are protected in some way by the parent. For example, the complicated metamorphosis which is so characteristic of starfishes is almost totally absent in those starfishes which are provided with brood-pouches. The same relation may also be exhibited when the larvæ of one species of a genus have become adapted to a mode of life very different from that of the larvæ of the other species of the genus. Thus those species of Æginidæ whose larvæ are para-

sitic multiply asexually during the larval life and build up complex communities, while nothing of the sort occurs in those species with free larvæ.

Many similar cases might be given, but we must bear in mind that they are all very different from the one now under examination. In all such cases the difference is between the larvæ of two distinct species, while in Alpheus we have a similar difference between the larvæ of individuals of a single species.

Among other animals it is not very unusual for certain individuals which are placed under conditions exceptionally favorable for embryonic development to be born in a more advanced stage than the normal for the species, and in such cases the larval metamorphosis is abbreviated by the omission of the earlier stages.

This abridgment of the larval life is not common, but many cases are known, and if the history of Alpheus were simply another illustration of this process of abbreviation it would not be at all anomalous, although the existence of three well marked and fixed grades of abridgment in *Alpheus heterochelis*, in three widely-separated localities, would still be remarkable and interesting.

The life history of the North Carolina form of this species is more abbreviated than that of the Bahama form, and the metamorphosis of the Key West form is still more shortened, but, in addition to the abridgment, the different forms also present most important differences in structure and in the order in which the appendages are developed; differences which are much more fundamental and profound than the mere length of the larval life.

The various larval forms are described with so much detail in the chapter on the metamorphosis of Alpheus that it is not necessary to repeat them here, but the following very brief outline will serve to call attention to a few of the most conspicuous features:

As several distinct species of the genus Alpheus pass through a long metamorphosis, each stage of which is almost exactly the same in all the species, we may safely assume that this is the primitive or ancestral metamorphosis which was originally common to all the species. It has been traced in *Alpheus minor* by me at Beaufort, North Carolina, and by Mr. Herrick in a similar species at New Providence. Mr. Herrick has also traced it at New Providence for *Alpheus normani* and *Alpheus heterochelis*. In all these forms the larva hatches from the egg in a form which is very similar to Fig. 2 of Pl. XVI, and very shortly after hatching it moults and passes into the second larval stage, which is the one from which Fig. 2 was drawn. This larva has all its appendages fully developed and functional as far backwards as the third pair of maxillipeds. Following these are three bud like rudiments, to represent the first, second, and fifth thoracic limbs, and posterior to these a long, tapering, imperfectly-segmented abdomen, ending in a flat triangular telson.

The locomotor organs are the plumose antennæ and the exopodites of the three pairs of maxillipeds.

After the second moult the larva passes into the third stage, which is shown in Pl. XVI, Fig. 1, and Pl. XVII, Fig. 1. The first and fifth thoracic limbs are now functional; all the abdominal somites are distinct and movable, and the uropod, or sixth abdominal appendage, has appeared, and its exopedite is functional and fringed with plumose hairs, while its endopodite is rudimentary. The five abdominal appendages have not yet appeared.

The first thoracic leg, which was represented by a bud in the preceding stages, has now acquired a flat, basal joint and a swimming exopodite like those of the maxillipeds, but its endopodite is rudimentary.

The fifth thoracic limb is fully developed and is the most conspicuous peculiarity of the larva at this stage of development. It has no exopodite; its basal joint is not enlarged nor flattened, and its long, cylindrical, slender shaft is prolonged at its tip into a long lance-like hair, which projects beyond the tips of the antennæ.

After its third moult the larva passes into the fourth stage, which is shown in Pl. XVIII, Fig. 3.

The carapace now begins to extend over the eyes, and the ears make their appearance in the basal joints of the antennules. There are now five pairs of plumose locomotor exopodites, belonging to the first, second, and third maxillipeds, and the first and second thoracic limbs. Between the latter and the elongated fifth thoracic limb are buds to represent the third and fourth. The telson has become narrow and elongated, and the uropods are fully developed, although there is as yet no trace of the other abdominal appendages.

After the fourth moult the larva passes into the fifth larval stage, when it resembles Fig. 1 of Pl. XXI, so far as concerns the anterior end of the body, from which it differs greatly as regards the telson and uropods. The eyes are now well covered by the carapace, and the swimming organs are the seven pairs of exopodites belonging to the three maxillipeds, and the first four thoracic limbs. The first five pairs of abdominal appendages are now represented by buds, like those shown in Pl. XXI, Fig. 1, but the telson and uropods are nearly like those of Fig. 3, in Pl. XX. The telson is narrow and much elongated, and its marginal spines are very small.

During the moults which follow, the abdominal appendages become fully developed, the eyes become completely covered by the carapace, the antennule develops a scale, the antennæ elongate, the swimming appendages of the midbody disappear, these appendages assume their adult form, and the animal gradually becomes like the young Alpheus shown in Pl. XX, Fig. 2.

This life history is common to *Alpheus minor* at Beaufort and New Providence and *Alpheus normani* and *Alpheus heterochelis* at New Providence, although the latter species presents a totally different life-history at Beaufort. Before it hatches, this form, as shown in Pl. XX, Fig. 1, reaches a degree of development which bears a general resemblance to stages two and three of the Bahama form, with certain differences which are pointed out in the sequel.

Immediately after hatching it assumes the form which is shown in Pl. XIX, Fig. 2, and Fig. 1. The animal has now all the somites and appendages of the adult, but all behind the maxillipeds are rudimentary, and there is little power of locomotion. The first moult occurs in a few hours, and the larva assumes the form shown in Pl. XX, Fig. 3, when it is no longer a larva but a young Alpheus. The eyes are almost completely covered by the carapace, the ear is well developed, the flagellum of the antenna has elongated, and the other appendages have assumed the adult form. An older specimen is shown in Pl. XX, Fig. 2, and a still older one in Pl. XVII, Fig. 3. Careful comparison will show that no exact parallel can be drawn between any larval stage of this form and a stage of the first form, and that we have to do with something more profound than simple acceleration of development. The Bahama *heterochelis* has, at first, three, then four, then five, and then seven fully developed and functional exopodites, while the North Carolina form never has more than three. As regards the thoracic region and the first five abdominal appendages the Beaufort larva, at the time of hatching, is more advanced than the fourth larval stage of the Bahama form, while the uropods are like those of the Bahama form at the time of hatching.

In the latter the first and fifth thoracic limbs are the oldest, and the others appear in succession, while all five pairs appear together in the Beaufort form. In the Bahama form the uropods appear before and in the Beaufort form after the others, and many minor differences show that we have to do with profound modification of the life history rather than with simple acceleration.

Packard's short account of the development of those specimens of this species which occur at Key West shows that these differ from the Beaufort specimens about as these latter differ from the Bahama specimens.

The second species is probably *A. saulcyi*, although Guérin's figure and description of this form are not in accord with it in some important points. It is found in the Bahama Islands, living in the tubes and chambers of two species of sponge, a green one and a brown one. Those found in the green sponges have many small eggs, while those found in the brown sponges have only a few large eggs. The eggs from the green sponge hatch in the stage shown in Pl. XXI, Fig. 1. It has rudimentary gills, the eyes are imperfectly covered, the antennules and antennæ are beginning to assume their adult form, and the exopodites of the three pairs of maxillipeds are the chief organs of locomotion, although all the appendages are represented. The abdominal feet are rudimentary, however, and the uropods are covered by the cuticle of the telson.

Very soon after hatching the larva moults and assumes the form shown in Pl. XXI, Fig. 2. The eyes are more completely covered, the antennules and antennæ are elongated, the thoracic limbs have the adult form and the pleopods are all functional.

In twenty-five or thirty hours after hatching it moults for the second time and passes into the third stage, which is shown in Fig. 8. It is no longer a larva, but a young Alpheus, with all the structural characteristics and pugnacious instincts of the adult.

In a few cases the development of this species is still more accelerated, and a few eggs from animals taken from the brown sponge hatched in the stage shown in Fig. 8, instead of the stage

shown in Fig. 1. The following notes on the variations in the coloration and habits in Alpheus, particularly in *A. saulcyi*, are taken from a paper by Mr. Herrick published in the Johns Hopkins University circulars.

VARIATIONS IN THE HABITS AND COLORATION OF ALPHEUS.

Some of the species of Alpheus are usually or even universally found living as parasites within the water tubes of sponges, and it is extremely interesting to find that individuals of the same species, living in different species of sponges, may themselves differ greatly in color and in habits.

A large brown sponge, *Hircinia arcuta*, which is not to be mistaken, grows on the shallow reefs and off the shores of many if not all the Bahama Islands. This is called the "loggerhead sponge" by the fishermen, and is found from just below low tide mark out to one-half a fathom or more of water, where its great size and sooty brown color distinguish it at once on the white bottom. If a sponge colony of this kind be pulled and torn apart, one is certain to find it swarming with a small species of Alpheus, which quarter themselves in the intricately winding pores of the sponge. Hundreds, or even thousands of individuals might be collected from a single large specimen. These animals vary from one-eighth to three-fourths of an inch in length. They are nearly colorless, excepting the large chelæ, which are tipped with brown, reddish orange, or bright blue. The females are so swollen with their eggs or burdened with the weight of those attached to the abdomen that they can crawl only with great difficulty if taken from the water. The eggs are few in number and of unusually large size, their diameter varying from one twenty-second to one twenty-fifth of an inch, and their number from six to twenty. These are most commonly yellow, but may be either bright green, olive, flesh color, brown, or dull white.

Another quite different sponge grows on all the reefs in from one to two fathoms or more of water. There are several varieties of this, which may be told by their olive-green color, yellow flesh, and clumpy, irregular shape, as well as by the putrescent mucus which some of them pour out when broken open. In nearly nine out of ten of these sponges one will find a single pair of Alphei which resemble those living in the brown sponge in most particulars, although they differ from them in several important points. They are distinguished by their large size, and by their peculiar and very uniform color. They vary in length from two-thirds to one and two-thirds inches. The females exceed the males greatly in bulk owing to the great size and number of their eggs.

Both sexes are nearly transparent and colorless excepting the large claws, which are bright vermilion-orange (Pl. IV). The female is practically inert during the breeding season (which lasted during our stay, March to July), and at such times is well protected in her sponge, or against any green surface, by the bright green ovaries which fill the whole upper part of the body, and by the mass of similary colored eggs attached to the abdomen below. Only two pairs, or four individuals, out of a hundred or more which were examined showed any variation from these colors. In these the eggs were yellow, and the pigment on the claws more orange than red. The table which follows shows the variations between two large females taken respectively from the brown and green sponges, and between the size, number, and color of the eggs.

Habitat of Alpheus.	Length of ♀	Number of eggs.	Diameter.	Color.	Color of adult.
	Inches.		*Inches.*		
Brown sponge....	$\frac{1}{2}$	19	$\frac{1}{22}$	Yellow (variable).	Large chelæ, red, blue, or brown.
Green sponge	$1\frac{5}{16}$	347	$\frac{1}{25}$	Usually green; in this case yellow.	Large chelæ, always orange-red.

These two forms, apparently distinct, are seen however, by closer examination, to belong to the same species, although they show very interesting variations. The Alpheus living in the brown sponges tends to vary in several ways, chiefly in size and in the color of the body and eggs. The rostrum usually has three spines, but occasionally only two are present, the median one being lost. It is evident that these animals are perfectly protected from outside enemies while within the tortuous mazes of the sponge, as their numbers would show. Parasites such as Isopods, how-

ever, are not uncommon. There has thus been no chance or need for natural selection to act along the line of color. On the other hand, possibly, the Alpheus of the green sponge does require color protection, since the females are very sluggish during the breeding season, which extends over a good part of the year. This animal is certainly well protected against any green surface, as already stated. But as will be shown, natural selection has probably nothing to do with it. The bright coloring of the tips of the claws, which only are protruded from the place of concealment, recall the similarly colored heads of boring annelids which abound on the reef, and may have a protective significance. This evidence, however, is not very reliable.

The colors of certain crustacea, and also the color of their eggs, are known to vary greatly with the surroundings. In the Alpheus parasites in the brown sponges these colors vary considerably where the surrounding conditions are the same. However, the color of the ovarian eggs is always the same as that of those already laid, and although these animals were kept for several days at a time in differently colored dishes, we never observed any very marked change in the color of the eggs, but these experiments were not continued long enough or carefully enough to be conclusive. The eggs of *Alpheus hecterochelis* are almost invariably of a dull olive color, while as in the case of the parasite of the green sponge, about one in a hundred has bright yellow eggs. In the first case at least this is possibly an instance of reversion to one of the original colors from which the green was derived by natural selection. In most species of Alpheus the color of the eggs is fixed and uniform, and as already suggested may have a protective significance, but in a few other cases where this is not true, the color is not only variable in different individuals, but probably also in the same individual.

In order to explain the variations which we find in these two forms, we must assume either (1) that the parasites of the green sponge are a fixed variety with distinct habits, or (2) that they represent individuals which have migrated from the brown sponges and adapted themselves to their new surroundings, or further (3) that only those chance individuals with orange-red claws and bright-green eggs, which occasionally occur in the brown sponge, find their way to the smaller green species, where they acquire great vigor and size. This last supposition is evidently untenable. If moreover the two forms, which were at first supposed to be specifically distinct, represent fixed varieties, we ought to find the young or at least adults of all sizes in both sponges, whereas it is only in the large brown variety that any small or undersized individuals occur, while a single pair, of large and tolerably uniform size, is invariably found in the exhalent chambers of the green sponges.

These and other considerations render it probable that the second (2) proposition above stated is the correct one, viz, that the parasites of the green sponges were born in the brown variety, and after attaining considerable size migrated thither, where they adapted themselves at once to their slightly different surroundings, growing to three or four times their former size, and the females acquiring bright green eggs, which become a source of protection in their new habitat. This view implies the greatest variability in color and in size of the individual, and in the color of the egg, which is more remarkable from the fact that it is quite unusual in this genus.

THE EMBRYOLOGY OF ALPHEUS.

At my suggestion Mr. Herrick undertook, in 1886, the study of the embryology of Alpheus, and devoted a considerable part of his time for three years to this subject, and while he carried on the work under my general supervision the results which he has reached are entirely his own, and my share in the chapter which is devoted to this division of the subject is only that of an instructor. I must call attention, however, to the fact that Mr. Herrick's studies were begun at a time when our knowledge of the embryology of the higher Crustacea was far less complete than it is at the present time. From time to time brief abstracts of the progress of the research have been written by Mr. Herrick and published in the Johns Hopkins University circulars, and the following corrected summary of his results contains the substance of these preliminary reports.

The work was begun at Beaufort, North Carolina, and the eggs of the two species of Alpheus which occur there were carefully examined and preserved for laboratory research, but much better and simpler material was afterwards obtained at the Bahama Islands, the early stages were much more thoroughly studied, and the development of the animals was traced in detail, step by step,

from the first nucleus of the fertilized egg, through all the embryonic and larval stages, up to the adult condition. The eggs of each of the thirteen species which occur in the Bahamas were obtained and studied sufficiently to ascertain what are the specific differences in development, and four species were studied exhaustively, in detail. These four are *Alpheus heterochelis*, Say; *A. minus*, Say; *A. saulcyi*, and the Bahama *heterochelis*. Unless otherwise stated the following notes on the early stages refer to the last species. The development in the egg is the same for all, excepting *A. minor*, which will be referred to separately.

This prawn has proved to be a good subject in which to study the origin and rôle of certain much disputed bodies, which are met with in several Crustacea, the "secondary mesoderm cells."

SEGMENTATION OF THE NUCLEUS AND OF THE YOLK.

The egg when laid, is enveloped by a single membrane, the chorion or shell, to which is added the secondary membrane of attachment. If the nucleus is unfertilized, it is not able to initiate the process of segmentation. The fertile nucleus divides, and its products pass towards the surface, until a syncytium of eight nuclei is formed. Either just before or after the division of these, the yolk undergoes segmentation simultaneously over the whole surface into a similar number of partial pyramids. Each yolk pyramid has a large nucleus at its base, while its apex fuses with the common yolk mass in the interior of the egg. The process is now a regular one until 128 to 256 small segments are formed. The rate of cell multiplication is then retarded over one-half of the egg, while it still continues and perhaps is accelerated over the remaining portion of it. The egg thus loses its radial symmetry and becomes two-sided. It is important to notice that no products of the segmentation nucleus are left in the interior of the yolk. The superficial pyramidal structure is lost; the primitive blastoderm is established, and there now takes place a general migration of nuclei from the surface to the yolk within, but principally, as would be expected, from that part of the egg where the blastoderm cells are most numerous, corresponding to the future embryo. This is followed by a partial secondary segmentation of the food-yolk into balls. The yolk-ball is apparently formed about the migrating nucleus, but as the latter is moving, this segmentation is irregular.

Mr. Herrick has been able to follow very closely the entire process of segmentation in Stenopus, where it is substantially the same as that just described, except that there is no general migration of cells from the surface, prior to invagination. This is also true of Pontonia domestica, and it is quite probable that the majority of macroura pass through the same phases in their early development.

Alpheus minor is anomalous from the fact that the products of the first nucleus instead of multiplying by regular binary division, multiply indirectly, and give rise to numerous nuclei, many of which degenerate, before the blastoderm is formed.

THE INVAGINATION STAGE.

A slight invagination occurs where the superficial cells are thickest, and the egg becomes what has been generally regarded as a modified gastrula. The depression is shallow, and does not form an inclosed chamber within the yolk. The included cells multiply rapidly, and form a mass of nearly similar elements, some of which pass into the yolk. The protoplasm surrounding the nuclei of these cells is prolonged into a reticulum, which encloses myriads of small yolk fragments, and probably digests them by an intracellular process, after the manner of feeding amœbæ. The thickening in front of and surrounding the pit, which is now obscured, is the rudiment of the abdomen. Anteriorly the "procephalic lobes" or more properly the optic disks make their appearance on either side of the long axis of the embryo, as circular patches of ectoderm. Meantime nuclei wander from the cell mass below the abdominal plate to all parts of the egg. Some pass to the opposite side, and take up a position beside the flattened epithelial cells, of what was the primitive blastoderm. The majority, however, pass forward and upward in divergent lines from the sides of the abdominal plate, and eventually large numbers of these wandering cells settle down over the dorsal surface of the embryo.

PRODUCTS OF CELL DEGENERATION.

At the beginning of the egg-nauplius period, when numerous wandering cells have passed forward and joined the inner surface of the embryonic ectoderm, certain new bodies begin to appear in great numbers. They vary in size from small refringent particles to bodies nearly as large as ordinary nuclei. The latter stain deeply and nearly uniformly, but with high powers it is often possible to demonstrate a clearer zone about them, which might be mistaken for a layer of cell protoplasm. How do these bodies, the so called "secondary mesoderm cells," originate and what is their function? As to their origin there can be no doubt whatever. They arise by a process of degeneration from the embryonic cells or nuclei, chiefly from those wandering cells just described. Many of the latter may be seen to be swollen out and their chromatin divided into coarse grains and balls of various sizes. The wall of the cell breaks down and thus sets the chromatin granules free, or, more correctly, the products of the degenerating chromatin.

These degenerating bodies are most marked in the fully developed egg-nauplius, where there is a large accumulation of them around the œsophagus and at the bases of the rudimentary appendages. After this stage they generally disappear from these regions. Somewhat later, however, when there is a well developed nervous system and six pairs of post-naupliar appendages, a patch of ectoderm cells on the surface of the egg opposite the embryo proper becomes noticeable. It reminds one of a median unpaired "dorsal organ." A slight invagination apparently takes place at this point, but at any rate a number of cells pass into the surrounding yolk, and these give rise in the way described, to a swarm of minute particles of chromatin products.

Before any pigment is deposited in the eyes, it is easy to demonstrate the presence of blood corpuscles in the stream of plasma which bathes the nervous system. They have the adult characteristics, that is, they possess a deeply staining nucleus and a clear irregular body. In the nauplius stage, moreover, some of the larger "secondary mesoderm cells" have a similar appearance, but there is no evidence that they ever become blood cells. Mr. Herrick's study of these bodies has shown that Reichenbach's views on the function of secondary mesoderm cells of Astacus are probably erroneous. According to this naturalist they arise from the nuclei of the endoderm cells, forming the ventral wall of the primitive stomach, and are converted into mesoderm.

THE GERMINAL LAYERS.

The apparent plasticity of the embryonic cells and layers and the comparative tardiness with which they are clearly differentiated can not fail to impress anyone who follows closely the early stages of development. The cell mass developed around the invaginate area, forming the thoracic-abdominal process, can not be artificially divided into layers. It certainly represents very largely the primitive mesoderm, but some of its elements pass to the opposite pole of the egg and become almost indistinguishable from the superficial ectoderm, although it will be shown that they do not pertain to this layer. A part of this mass remains as the mesoderm of the rudimentary abdomen, while many of the cells which migrate from it degenerate and perform a nutritive function.

The endoderm does not appear as a definite layer until the egg-nauplius stage. It arises from wandering cells which assume a peripheral position, and, joining the cells of the hindgut, form the walls of the mesenteron.

THE EYE.

The optic discs appear as patches of ectoderm, one cell thick on either side of the long axis of the embryo in front of the rudimentary abdomen. Before the appendages are definitely formed, these have become thickened ectodermic discs. This thickening is due (1) to delamination, or to a division of cells in a plane parallel with the surface; (2) to emigration of cells from the surface, due to crowding or to a division of superficial cells in a plane at right angles to the surface. A disc of cells is thus formed which gives rise chiefly to the eye and its ganglia. The cord of cells uniting the two optic discs represents mainly the future brain. The eye proper is due to the differentiation of the outer layer of the cells of this disc, while the ganglion is developed from the inner layer. For fuller results of later studies not represented by these partial and preliminary notes, reference must be made to Mr. Herrick's completed paper and to the summary of the whole history of the development in the egg given at the end.

GONODACTYLUS CHIRAGRA.

There are few orders of animals of which we are more ignorant than we are of the Stomatopods. They are well known as museum specimens, and every natural-history cabinet contains one or two, which have been brought home as rare curiosities from distant seas; but we know hardly anything of the habits of the living animals. They are abundant and widely distributed, but like most rapacious animals they are very alert, taking alarm at the slightest disturbance and retreating to the depths of their burrows at the bottom of the ocean, where they are so completely hidden from observation that their capture is difficult, and any attempt to study them in their homes is almost out of the question.

The habits of Squillæ are tolerably well known, and in my report on the Stomatopoda, collected by H. M. S. *Challenger*, I have given an account of the habits of Lysiosquilla based upon observations made at Beaufort, North Carolina; but, except for a few scattered and fragmentary notes in the various descriptive papers, this is the whole of our knowledge of the order. During the seasons of 1886 and 1887 I was so fortunate as to find in the Bahama Islands *Gonodactylus chiragra* living in localities which were peculiarly favorable for observing its habits, and I am now able to supplement my report upon the *Challenger* collections by an account of this interesting species, of which little had hitherto been known, except the fact that it is the most cosmopolitan of the Macroma abounding on the shores and islands of all tropical and subtropical seas.

I also obtained its eggs in abundance and succeeded in rearing the young from them in aquaria, and am now able to make a contribution to a subject upon which there were hitherto no direct observations, for it is a noteworthy fact that while the older larvæ of Stomatopoda have long been known, and while many genera and species of them were carefully figured and described and named by the older naturalists before their relationship to the adult Stomatopoda was suspected, not a single species in the whole order has, so far as I am aware, been reared from the egg and in this way identified with its specific adult.

While the adults usually inhabit burrows in the bottom the larvæ swim at the surface of the ocean, and as none of the animals which are captured in the surface net exceed them in beauty and grace, their glass-like pelagic larvæ are familiar to all naturalists who have had an opportunity to study the surface fauna of the ocean. Their perfect transparency, which permits the whole of their complicated structure to be studied in the living animal, their great size and rapacity, the graceful beauty of their constant and rapid movements, can not fail to fascinate the naturalist. Unfortunately they are as difficult to study as they are beautiful and interesting, and notwithstanding their great abundance and variety, only two or three of them have been traced to their adult form.

Unlike most Malacostraca the Stomatopoda, instead of carrying their developing eggs about with them, deposit them in their deep and inaccessible burrows under the water, where they are aërated by the currents produced by the abdominal feet of their parents. The eggs quickly perish when deprived of this constant current, and as it is very difficult to obtain them at all, I know of no Stomatopod which has ever been reared from an egg under observation. The older larvæ are hardy and are easily reared, but they are seldom found near shore, and microscopic research is so difficult at sea that I know of only two cases in which they have been kept until they assumed the adult form. As I have stated in my report on the *Challenger* Stomatopoda, I have reared a young Lysiosquilla excavatrix from an old larva which was captured at the surface, and Faxon has in the same way obtained the young Squilla empusa. The young larvæ are common near shore, but as they seldom survive a moult in captivity they can not be identified in this way.

The growth of the larvæ is slow and the larval life long, and as they are as independent and as much exposed to changes in their environment and to the struggle for existence as the adults they have undergone secondary modifications which have no reference to the life of the adult, and are therefore unrepresented in the adult organism. The larvæ have been arranged in genera and species, but their generic characteristics are quite different from those upon which the adult genera are based, and this is true in a still greater degree of their specific characteristics. As they undergo great changes during their growth different stages have been described as distinct species or even genera, and it is not easy to select from the rich gatherings which are brought home by

collectors the successive stages in the history of a single species. Like the adults, they are widely distributed, and a gap in a series from the North Atlantic may be filled by a specimen from the coast of Australia or the Sandwich Islands, and the collection from a single locality may contain the larvæ of several widely-separated species of adults in all stages of growth as well as the larvæ of deep-water species which are as yet entirely unknown.

The attempt to unravel the tangled thread of the larval history of the Stomatopods is therefore attended with very exceptional difficulties, and the earlier writers were content to rest after the bestowal of generic and specific names upon the larvæ. As I found after the *Challenger* collection was placed in my hands that it was very rich in larvæ, I attempted to determine, by comparison, the larval series for each genus, and the methods which I employed for making the comparison are fully stated in my report. As one of the results of this comparison I ventured to describe the general characteristics of the larva of the genus Gonodactylus (p. 113), and in Pl. XII, Fig. 5, of that report I figured a larva which I ventured to call the larva of Gonodactylus. A comparison of that figure with Pl. XV, Fig. 11 of this memoir will show that this determination was correct, for the larva of *Gonodactylus chiragra* which is here described is so much like the one figured in the *Challenger* report that they belong, in all probability, to the same species.

CHAPTER II.

THE LIFE HISTORY OF STENOPUS.

By Francis H. Herrick.

This paper is the result of observations made at Beaufort, North Carolina, in 1881 and 1883, and at Nassau, New Providence, in 1887. The marine laboratory of the Johns Hopkins University was stationed at the latter point in the Bahama Islands from March until July of that year, and with the means thus generously afforded, I was able to considerably extend my studies upon the Crustacea of these coral islands.

Professor Brooks found a number of peculiar pelagic larvæ at Beaufort, and it is very probable that they represent a part of the life history of *Stenopus hispidus*. Plates IX and X, illustrating two important stages of these very interesting larvæ, are contributed by Professor Brooks, and the descriptions of these stages are based entirely upon his observations.

While the material gathered in a sojourn of a few months at the seashore is in many instances incomplete, it seems worth while to bring out this sketch of the Stenopus, inasmuch as nothing was previously known of its development, and indeed but very little concerning the adult form. *Stenopus hispidus* is, in fact, generally known to naturalists as occurring only in the Indian and South Pacific oceans. It was at first quoted from the Atlantic (Cuba) by Von Martens (7) in 1872, and it has not since been reported from the Western Continent, so far as we are aware, until we rediscovered it at Abaco, Bahamas, in 1886, but any assiduous collector on West Indian coral reefs must somewhere have hit upon it (V. Appendix I).

As the eggs are quite small, as is the case in all Crustacea with a protozoa stage, they are not particularly well suited for study by means of sections, and no special attempt has been made to trace out the history of the germinal layers, a subject which can be dealt with to better advantage in other species. The Stenopi breed readily in aquaria, and several series of eggs, illustrating fully the segmentation, and some early phases of development were prepared, and the sections were afterwards made in Baltimore. These are given on Pl. VI. They are especially interesting, since the segmentation is like that of Penæus studied by Haeckel, who relied wholly upon surface observations.

The ova were immersed in Kleinenberg's picrosulphuric acid and afterwards hardened in alcohol. This answered sufficiently well for the purpose in hand, although it rendered the eggs more resistant than is desirable.

I.—THE NATURAL HISTORY OF STENOPUS.

The Bahaman Stenopus (Pl. V) measures from $1\frac{1}{2}$ to $1\frac{3}{4}$ inches in length. All the appendages are long and generally quite slender and delicate, especially the antennæ, which give to this form a very characteristic appearance in the sea. These are snow-white. They are carried widespread and arch outwards in graceful curves. The flagella of the second or outer antennæ are two and a half times the length of the body. In the act of swimming these are bent backward and outward, while the outer division of the first or inner antennæ is carried upward, and their inner branch is directed forward.

The body is pure white or nearly so, excepting three broad transverse bands of reddish scarlet. The first or most anterior of these color bands covers the front of the animal, involving the eyes and bases of the antennæ, and in some cases it extends behind the rostrum as far as the mandib-

ular or "cervical" groove. The second is nearly confined to the broad tergal surface of the third abdominal segment, while the third zone crosses the last abdominal somite and impinges on the tail fin. The appendages are all colorless excepting the third pair of legs which carry the large pincers. These are similarly marked with four bands of the same bright color. As shown by the colored plate two of them encircle the great claws, a third belongs to the carpus, and the fourth to the meros or fourth segment of the limb. The bases of the third and sometimes of the fourth and fifth thoracic legs are tinged with bright blue. The ovaries often give to the dorsal surface of the females a light-greenish cast.

There is but little variation in the size and character of these markings in the same sex or in different sexes, but it is most remarkable to observe how constant these colors are in individuals of the species from different parts of the world. We possess two colored drawings of this species* (which will be referred to again), one by Adams (5), from a living specimen taken in the China Sea, and the drawing of Dana (6), who found the species on the coral reef of Raraka, one of the Paumotu Islands, and at Balabac Passage, north of Borneo. Both of these, and especially the Samerang plate, essentially agree with our Bahaman specimens, which in color seems to be the more faithful copy of nature. Here the basal joints of the thoracic legs are colored blue as in the Nassau form. Why should Stenopus, coming from different seas, retain the same colors and markings, to a nicety of shade and pattern, while a cosmopolite like *Gonodactylus chiragra* (a Stomatopod) presents such wide color variations as to be as unlike as possible, so that scarcely any two taken from the same place have a similar color pattern? To this question we can not at present give a satisfactory answer.

Alcohol soon removes all trace of color from the body, but the spots on the legs remain for a longer time as light orange red. Both sexes are of nearly the same size, and, as already stated, alike in color.

Being thus brilliantly decorated with the American colors, our crustacean soon acquired with us the name of the "Bandanna Prawn." As we see this animal swimming deliberately in the water we are reminded of some strange and fantastically colored insect. It is by far the most showy, and for its size the most attractive, member of that giant family, the Crustacea, which have their dwelling on the reef. One day, when out upon a wading and diving expedition, a pair of these prawns was discovered by turning over a plate of loose coral, and was easily captured by slowly raising the slab from the water into the boat; for this species, unlike some shrimps, is quite helpless when once out of its element. More frequently, however, they led us to a long chase.

There seems to be considerable attachment between the sexes, since they are invariably found in pairs, the male and female swimming side by side. On a still day they may be found clinging to the mosaic of sponges and living coral, which form the reef bottom, but if disturbed they suddenly become very active, and, darting backward by sudden jerks, dive into some chink, out of reach of the hand net.

Several females both hatched and laid eggs in aquaria in the month of June, but the breeding season, as inferred from the capture of locomotor larvæ, probably extends throughout the spring and summer months, if not throughout the entire year.

The eggs are very numerous. They are nearly spherical and measure one-fiftieth of an inch in diameter. They were always of the same light opalescent-green color. The ova are laid at night, but the process was not observed.

Three different females hatched their broods on the afternoons of June 4, 14, and 24, respectively, and moulted and laid eggs during the following nights. As these animals invariably moult just before laying their eggs, the latter are probably fertilized at the time they are laid. The hatching of one brood lasted about 9 hours, from 2 o'clock in the afternoon until well into the following night. By 10 o'clock the same evening some of the larvæ had moulted for the first time. The eggs are closely felted to the abdomen, and, as in all Decapods, they are cemented together by a secretion which possibly comes from the oviducts during ovulation. They are fastened by the same substance to the hairs which fringe the bases of the pleopods, chiefly to those of the first and second pairs.

---

* Besides Milne-Edwards figure (4), evidently made from a specimen in which the natural colors had been removed by alcohol. (See remarks, etc., under Section IV.)

After a moult the colors are, as is usual, very bright, and the moulted skin, as it stands intact supported by the antennæ, may easily be mistaken for the living animal. These prawns make no sounds and appear to be very timid. The surface of the whole anterior body and of the large claws is thickly beset with tooth-like spines, the points of which are bent forward, and these may be regarded as an admirable protection against being swallowed head first by an enemy. It is also interesting to notice that the spines of the hinder part of the body project backward, and may thus be of service to Stenopus when attacked from the rear. Their long sensitive antennæ or "feelers" and well-developed eyes doubtless warn them of approaching enemies, which, by their rapid angular movements, they may easily escape. The extraordinary development of the eyes in the older larvæ (Pl. II) is remarkable.

The geographical distribution of *Stenopus hispidus* is very interesting.* H. Milne-Edwards, in his "Histoire naturelle des Crustacés" (3), gives the habitat of *Stenopus hispidus* (Latreille) as the "Indian Ocean," following Olivier (1) and the older writers. In the "Règne Animal" of Cuvier, third edition, "Les Crustacés," p. 137, he says: "We know of only one species, reported from the Australian seas by Peron and Lesneur." The Samarang naturalists (5) met with it on the coasts of Borneo and at the Philippines in 1843–'46. Dana, in 1838–'42, on the Wilkes Expedition (6), found it in the South Pacific at the points already noticed. In 1872 E. von Martens (7) describes the species for the first time from the Atlantic, in a collection of Cuban crustacea made by Dr. J. Gundlach, and de Man in 1888 (9) quotes it from Amboina in his monograph on the Decapoda and Stomatopoda collected in the Indian Archipelago by Dr. J. Brock.

We can now add to this list the Bahama Islands (Abaco and New Providence). We have also the interesting fact that the larva was taken on our coast at Beaufort, N. C., whither it had probably been carried by the warm waters of the Gulf Stream. We may therefore expect to find the adult Stenopus on the Florida Keys, but not much farther north, since this is essentially a tropical form.

We thus have in *Stenopus hispidus* another instance of not only the same genus, but also the identical species, occurring on the eastern shores of two continents. It seems not impossible that the prolonged larval period which this animal possesses may have played an important part in its geographical distribution. This may be also true of *Gonodactylus chiragra*, but on the other hand it can not be asserted of Limulus. In the last case the Asiatic and American forms are specifically distinct.

II. SEGMENTATION AND EARLY PHASES OF THE EGG.

The prawn, which hatched her zoëa brood on the 4th of June, laid eggs the next morning probably at about 6 o'clock, and as soon as discovered some of these ova were hardened at intervals of a few hours during the next two days. In this way a complete history of the segmentation was obtained.

First stage.—The first eggs preserved (probably 5 to 6 hours after ovulation) are perfectly opaque, nothing but the light-green yolk corpuscles showing through the shell or egg-envelopes. Thin sections prove that the segmentation nucleus has divided, and that its two products lie remote from each other. Physiologically speaking, we now have two cells, each consisting of a deeply staining nucleus and perinuclear protoplasm. The first segmentation is evidently central. What takes place is briefly as follows: Primitively we have a central nucleus, about which protoplasm is gathered. Around this again is the great mass of yolk, and the whole is encapsuled by the protective chorion and the secondary membrane of attachment. The first division involves only the nucleus and surrounding protoplasm. The products as independent bodies now leave their central position and seek the surface of the egg. In one instance one of these has reached the surface (shown in Pl. VI, Fig. 1), while the other is only halfway there on the opposite side. The superficial cell, as seen by the figure, has the same characters as when buried in the yolk. In

* The reason for considering the Bahaman form identical with the Hispidus of Olivier, Latreille, Milne-Edwards, Adams, Dana, and others are given on page 351.

another egg of the same phase neither cell is quite at the surface, so that the example given in Fig. 1 may be taken to illustrate a tendency, not a rule.* The yolk (Fig. 1, Y. C.) consists here, as in subsequent stages, of homogeneous and tolorably uniform green corpuscles. No vacuolar cavities are to be seen.

Second stage.—Four and one-half hours later the second segmentation is going on or is already completed. The egg from which Fig. 2 was taken contains four nuclei with perinuclear protoplasm. It was cut into a series of 50 sections, of which the second represented is the twenty-first. Nuclei occur in sections 21, 25, 29, and 35, none being as yet superficial. A portion of section 21 (Fig. 2) is shown under a higher power in Fig. 3.

Third stage.—After three hours and twenty-five minutes have passed the third phase is reached and we have eight cells, around which the yolk is superficially constricted into eight corresponding lobes or segments. A surface view of this entire egg and also a section through it are shown in Pl. VI, Figs. 5 and 6, and a tangential section of one of the nuclei and lobes is given with more detail in Fig. 4. The constriction furrows appear to be considerably deeper than they actually are, and we might predicate a total segmentation of this egg without the knowledge which the section affords. We have here a merely superficial indentation of the yolk, the great central mass of which is undivided. It is a close approach to the yolk pyramid stage seen in Astacus, Alpheus, Hippa, Palæmonetes, and many other Decapods. The dividing planes, Figs. 7 and 8 (unless artificially produced), do not penetrate into the egg. The furrows extend inward to a plane just below or on a level with the nucleus.

Each nucleus with its outer protoplasm may be spoken of as the *cell*, and it is hardly probable that there is any protoplasm like that surrounding the nucleus in the other parts of the egg. The nuclei increase gradually in size, as seen by comparing the figures of successive stages, and the surrounding plasm, which they manufacture out of the yolk, is also of greater bulk. Each is a flattened, oval disc, shown well in transverse section in Fig. 5 at *a*, and tangentially in Fig. 4. It contains coarse grains and granules of chromatin, and the enveloping protoplasm radiates visibly but a short distance between the yolk spherules. The long axis of each nucleus lies in a plane parallel with the surface. Cell multiplication is in all cases indirect, as my observations show to be the case with several other related forms, and this is undoubtedly the rule not only with the segmenting eggs of the Decapod Crustacea, but with those of all the Metazoa. There seems to be an exception in the case of *Alpheus minor*.

Fourth stage.—After another interval of an hour and five minutes there are sixteen cells resulting from the fourth segmentation. The blastomeres are less sharply marked at the surface and more distinctly polygonal. Six nuclei are cut by the section given in Fig. 7. They are nearer to the surface than in the former stage.

Fifth stage.—The egg represented by Fig. 8 is three hours older than the last and has thirty-two cells and the same number of superficial segments. Up to this time the egg has exhibited radial symmetry. The nuclei are quite near the surface of the egg. They are more spherical and the investing protoplasm is less conspicuous than formerly. The fissures between contiguous blastomeres are becoming less and less prominent.

Sixth stage.—After a longer period, nine hours and forty-five minutes, the process of regular division into smaller and smaller superficial segments has proceeded until 128–256 of these bodies are formed. The cells lie at the surface, just under the chorion, and form a continuous envelope, the primitive blastoderm about the central yolk. This yolk mass is not segmented, nor does it include any nuclei which have not participated in forming the blastoderm. In one or two instances a cell was observed just below the service. This may be interpreted as either having never reached the surface or as having been there and moved below it towards the interior. But the general statement is doubtless true that all cells reach the surface, and that there is no extensive migration to the interior, as there is in Alpheus, before invagination.

---

* It now seems probable to me that this superficial cell represents the male and the central cell the female pronucleus. A small, deeply staining body, which I interpret as an undoubted polar cell (not shown in Fig. 1), lies underneath the chorion, not far from the superficial cell.

Seventh stage.—In three hours and three-quarters from the last phase the blastodermic cells have spread more rapidly at a given point on the egg, which loses its radial symmetry in consequence. There is thus formed the embryonic area or first trace of the embryo proper.

Eighth or invagination stage.—Three and a half hours later a portion of the blastoderm in the embryonic area is invaginated, that is to say, some of its cells pass below the surface in a body, and the invagination stage is reached. The invagination is solid, or nearly so, as is the case with nearly all Decapods. Fig. 9 represents an oblique section of one end of an egg, through the area of invagination, *Ig.* The epiblastic cells contain small oval nuclei. There are no yolk cells in the interior of the egg. The vitellus is here segmented into large, irregular fragments, each of which is composed of yolk corpuscles similar to those seen in Fig. 4. It is just possible that this fracture of the yolk, which is commonly seen in the eggs of other Crustacea, is artificially produced at least to some extent, at this stage.

Ninth stage.—After another period of three and a half hours, while the external change is not marked, the invaginated cells have rapidly multiplied and given rise to a considerable cell-mass below the surface at that point.

Tenth stage.—In thirteen and a half hours from the last stage, or when the embryo is fifty-two hours old, important changes have been effected. In surface view the embryo presents a heart-shaped or somewhat three-sided area. The optic discs appear as widely separated patches of ectoderm, united to the thoracic-abdominal plate, a mass of cells which forms around, but chiefly in front of, the point of ingrowth. Sections through this egg show a considerable thickening in the optic discs, and an accumulation of large granular cells in the abdominal area. These latter undoubtedly represent some of the primitive mesoderm and endoderm.

The phenomena just recorded are given in a more condensed form in the following table, which shows the age and corresponding growth of the embryos at the successive stages. The age of the first stage is assumed to be 6 hours, which is probably not far from the truth.

In the above account we are constantly dealing with different eggs, and assume of course that they are all at any given time in the same phase of development. While this is not strictly true, it is very nearly so. The eggs are at first about on a par, and it is only later that some become handicapped, producing those slight differences which may be seen in embryos from the same female.*

Time of hatching June 4, a. m., early. Temperature 80° F. Diameter of egg $\frac{1}{80}$ inch.

Stage.	Age of egg.	State of development.
1	6 hrs	2 cells.
2	11½ hrs	4 cells.
3	14 hrs. 55 min	8 blastomeres.
4	16 hrs	16 blastomeres.
5	19 hrs	32 blastomeres.
6	28 hrs. 45 min	128–256 blastomeres.
7	32½ hrs	First trace of embryo.
8	35½ hrs	Invagination stage.
9	38½ hrs	Pit obscured.
10	52 hrs	Optic discs and abdominal plate formed.

We thus have in Stenopus a type of the so-called "centro-lecythal" segmentation, exactly comparable to that of Penæus, and essentially like that which is probably characteristic of a large number of the Decapod Crustacea. The fact that all the protoplasm of the egg enters into the blastoderm and that no yolk cells are now formed, is of some interest, and this subject, will be considered more fully in a paper on the development of Alpheus.

* This is not true of the American lobster, *Homarus americanus*, in which I have made a very complete study of the segmentation process. In a batch of segmenting lobster's eggs, there is a decided lack of uniformity. Some ova which afterwards continue to develop, remain with yolk unsegmented until the third or fourth day after fertilization.

III. METAMORPHOSIS, OR PERIOD FROM THE TIME OF HATCHING TO THE ADULT STATE.

A. Protozoëa or first larva (length=4^{mm}).—Stenopus leaves the egg as a protozoëa, which may be compared to one of the early larvæ of Penæus or Sergestes, but it is unlike either of them. This first larva, which is very long and slender, is so coiled upon itself in the egg that the tail fin overlaps the posterior end of the carapace. It requires considerable time after casting off the shell to uncoil and straighten its appendages, especially the antennæ and the long rostrum which was bent under its body.

The figure on Pl. XI exhibits some of the grotesqueness of this larva. This drawing was made from an animal which had just wiggled out of its egg shell and was uncoiling its appendages. The huge antennæ are partially unfolded, while the rostrum R., is scarcely visible. Drawings of parts of this immature protozoëa are seen in Pl. VII, Figs. 11–16, and the larva itself as it finally appears, about two hours after hatching, in Fig. 11. If we compare with this the younger form in Fig. 25, we notice some details, chiefly of a quantitative kind, in which they differ. Immediately after leaving the egg the epidermic structures grow rapidly; hairs or setæ are developed on all the appendages, and the tail-fin acquires some new characters. The first larva does not swim well until several hours after hatching.

The Stenopus protozoëa (Pl. VII, Fig. 11) is 4^{mm} long, the rostrum alone being 1½^{mm}. It is colorless, excepting the dark eyes and a few scattered blotches of brownish pigment upon the sides of the body or on the tail-fin. It swims chiefly by aid of its largely developed antennæ, which are directed forward as shown in the plate. These, with the rostrum, add considerably to the apparent length of the body and serve to distinguish it, without the aid of a lens, from the second larva (Pl. VIII, Fig.17), which soon follows and swims about in the aquarium with the others. It is further characterized by the very large size of its mandibles (Pl. XI, Fig. 25, Md.) and by its forked telson-plate, adapted for swimming. The forked locomotor tail-fin and large hairy antennæ mark the protozoëa stage in Crustacea generally. The carapace is only feebly developed, not nearly reaching to the bases of the appendages. It is prolonged in front into a huge tapering cone, the rostrum, which is nearly half the length of the body. This is beset with short spines and reaches considerably beyond the antennæ. About four segments of the abdomen are distinguishable from before backwards (Fig. 25). The first and second, which latter is the largest, carry lateral spines, and the upper surface of the second segment is also prolonged posteriorly into a median spine. The tail-fin at the time of hatching is sharply forked (Fig. 13) and is furnished with 6 pairs of rudimentary setæ, of which the median pair is the shortest, besides a pair of outer non-plumose bristles (Figs. 11, d, and 13, a.). In the course of a few hours this organ has become functional and appears as shown in Fig. 11. The hairs grow out and acquire thick lateral fringes; the outer pair (next to *a*) become rudimentary, and three additional pairs of toothlike bristles make their appearance on the sides of the telson-plate.

The eyes are sessile. The inner or first antennæ (Fig. 25, AI) are jointed, unbranched appendages. Each is tipped with a bunch of about four long sensory filaments and with a single seta. A single plumose hair also springs from the distal end of the penultimate joint on its inner side. The outer antennæ are biramous. The inner branch consists of a simple stem, tipped with at least two long hairs. The outer division is segmented at its extremity, and is garnished with plumose setæ, chiefly on the inner margin, there being one or two to each segment. The gland at the base of the antennal peduncle is conspicuous.

The mandibles are of enormous size in comparison with the other appendages. A view of the labrum and right mandible is given in Pl. VII, Fig. 15. They are simple blades with rounded edges, covered with minute horny teeth. There is no palpus. The first maxilla (Fig. 12) consists of two stout branches tipped with bristles, and in the case figured they are spotted with pigment. The second maxilla is a broad lobulated plate (Fig. 10). Each lobe is provided with hairs, excepting the outermost which corresponds, in part certainly, to the scaphognathite. Only a single bristle was detected on this lobe in the specimen from which the drawing was made.

The three maxillipeds have each an exopodite, which is considerably larger than the other branch, and which is furnished near the tip with not less than three pairs of locomotor hairs. The undeveloped condition of these latter in an embryo just hatched but unable to swim, is well shown by

Figs. 14 and 16, which represent the first and third maxillipeds of the right side, as seen from below. The endopodites of the second and third pairs possess four joints, of which the terminal one carries setæ. There is one pair of thoracic limbs consisting of a stout locomotive exopodite, similar to that of the second and third maxillipeds just described, and of a very short, indistinctly segmented endopodite. The latter is armed with two terminal and three lateral plumose hairs on the inner side.

B. *First zoëa or second larva* (length, $\alpha=5^{mm}$).—Five or six hours after hatching the protozoëa moults into a form which superficially resembles the macrouran larval type. (Pl. VIII, Fig. 17.) The carapace of this larva has grown down so as to cover the basal joints of all the appendages, and it also extends behind them. The rostrum is reduced to from one-half to two-thirds its former size, and does not surpass the antennal hairs.

There is still put one thoracic segment with its appendages. All the abdominal segments are formed, but none show any traces of limbs. The lateral spines of the first and second somites are missing, but the median unpaired spine of the latter is greatly developed, and extends to nearly the end of the third somite. The sixth somite, which carries the zoëal telson, is equal in length to the third, fourth, and fifth combined. The fan-shaped telson, viewed from below, is represented in Fig. 20. Comparing this with Fig. 11, we observe that it is no longer conspicuously forked. The median notch has a short unpaired spine. There are six pairs of feathered hairs, the outer ones still being rudiments exactly as in the first larva, and a non-plumose spine which ends the series; the three rudimentary spurs seen in Fig. 11 being wanting. The eyes, which have acquired short stalks, protrude slightly.

The antennæ are shorter and are now no longer so important as organs of locomotion. The terminal joint of the inner antenna is reduced, but otherwise this appendage is but little changed. The outer antenna ends in a stout hook, which is succeeded, on the indented margin of the inner side, by a series of eight feathered hairs. The second joint of this appendage also bears a serrated hooked spine at its outer extremity. The mandible is without a palp. It has a serrated edge, and a prominent, inferior, compound tooth (Fig. 18).

The inner branch (coxopodite) of the first maxillæ (Fig. 19) carries three simple and three compound spines, while the outer division consists of three segments with stout, plumose hairs, as shown in the figure. The second maxillæ (Fig. 21) are considerably altered from the form shown in Fig. 10. There is an outer lobe (scaphognathite), bearing one large hair directed backwards and at least four others which point in the opposite direction. The inner portion is lobulated into six or more parts, all of which are well provided with stiff hairs.*

The first maxilliped is shown greatly enlarged in Fig. 22. Examining this in connection with Fig. 14, we find that the exopodite consists of one segment and bears a limited number of hairs (here two) at its apex. The endopodite is segmented and carries numerous hairs, which are continued in small tufts along the inner margin to the base of the limb. The chief swimming organs are the first and second maxillipeds and the first pair of thoracic legs. The inner branch of the latter is considerably developed, and nearly equals the expodite in length.

There is a large irregular spot of red pigment on each side of the anterior half of the body just above the base of the third maxilliped. The lobes of the liver (L) begin now to show distinctly through the carapace. The food yolk, which is present in small quantities in the stomach of the protozoëa (Fig. 25), is finally absorbed. It was probably owing to this and to the fact that I gave the larvæ no food that suited their taste that they never reached the second moult, although they passed a number of days in this condition. In course of several trials the animals at this stage always became greatly crippled by particles of organic matter adhering to their body and invariably starved. For later stages, therefore, connecting this zoëa with the adult, we have to rely upon larvæ collected at the surface of the ocean.

C. *Mysis or Schizopod stage.*—It is evident that the zoëa of the stage B passes into a mysis-like form through the intervention of one or more moults, and we have two larvæ already noticed belonging to the close of this period. They were collected by at Beaufort, N. C., July 14 and 15,

* The distal or terminal lobe represents the endopodite; the lobes next this stand for the basipodite, while the second (?) proximal division at the base of the appendage correspond to the coxopodite.

1883. In the Beaufort specimen (Pl. IX) all the segments and appendages of the body are present, and all of the latter are functional, excepting the first five pairs of abdominal feet, which are rudimentary buds. The carapace is well developed, and terminates in front in a slender serrated rostum, which is much shorter than in previous stages. The eyes are now large and prominent, being mounted on long stalks. These organs, which are sessile in the protozoëa, undergo marked changes in both size and form in the course of development. They reach a maximum in a later stage, and are correspondingly reduced during the passage from the latter to the adult.

The inner antennæ are biramous; the outer are reduced to a long narrow scale, armed with bristles. The third pair of maxillipeds and first, second, third, and fourth pairs of thoracic legs bear prominent swimming exopodites. The fifth pair of pereiopods characterize this larva by their great length, and by the huge, paddle-shaped segment, which bears the small, terminal claw. There is no exopodite to this appendage. The endopodites of the first, second, and fourth pereiopods are nearly equal; the third longer. The first five abdominal segments are of equal size and, as stated, carry rudimentary feet. The sixth segment, however, is long and narrow, and has the uropods well developed.

D. *Mysis stage.*—The larva of stage *C* moulted into a form (Pl. X) resembling the last, with the addition of several important features. The inner antennæ consist, as before, of a segmented stem with two terminal appendages. The first and third segments of the antennular stalk are short, while the second is very long; spine nearly equal to length of basal segment; inner flagellum very slender, shorter than the outer branch; the proximal, thickened portion of which carries several (three) bunches of sensory filaments.

The antennal scale is as long as the antennular peduncle. The flagellum of the antennæ now appears as a slender filament, nearly twice the length of the scale. Possibly it is formed, as in Penæus, from a bud-like remnant of the inner ramus of this appendage in the protozoëa. The third pair of maxillipeds and first to fourth pairs of thoracic legs are as in the previous stage, with conspicuous exopodites fringed with setæ. The endopodite of the fourth pair is longer than that of the third; the fifth pair are twice as long as the fourth; and the breadth of the penultimate segment is much reduced.

The first, second, and third abdominal segments are equal; the sixth is narrow, equal to length of fourth and fifth. The telson is narrow, tapering, three times as broad at base as at apex; the uropods are one-fourth larger than telson. Pigment is found as before, in the extremities of the segments of the appendages. Large spots also appear on the abdomen and eyes.

E. *Mastigopus stage.*—On June 15 an older larva than the one just described was obtained in the ocean outside the harbor at Nassau. It agrees in the main with the mastigopus of Sergestes. The carapace ends anteriorly in a short spine or rostrum, which is bent up at an angle of about 40 degrees with the body. The eyes are mounted on very long naked peduncles. Both pairs of antennæ are biramous. The outer flagellum of the first or inner pair of antennæ is the longest (Pl. XI, Fig. 26), and it bears four or five bunches, containing in all about a dozen sensory filaments. The inner branch is a bud. The second antennæ extend as far forward as the joint of the first pair, where the inner flagellum is given off. The flagellum of the second pair is wound into a short spiral coil.

The exopodites of the second pair of maxillipeds are rudimentary (Pl. XI, Fig. 31). The third maxillipeds are now the stoutest appendages, and equal in length the third pair of thoracic limbs. The first and second thoracic legs are slender; the third pair is the longest and the terminal segment is bifid; the fourth is a short two-jointed rudiment; the fifth, corresponding to the huge oar-like appendage of stage *C*, is reduced to a bud. *It thus appears that, as in the Sergestids, the last two pairs of walking legs are shed after the mysis period, to be reconstructed again in the mastigopus stage.*

All the abdominal appendages are functional. (Pl. XI, Fig. 27.) The last segment of the abdomen is nearly equal in length to the three preceding. It is laterally compressed, and more nearly resembles the adult form. In the act of swimming this larva carries the abdomen bent at nearly a right angle to the rest of the body. It is colorless, excepting areas of red pigment at the bases of the abdominal feet, and spots on the lower portions of the antennæ and eye-stalks. There is also a transverse band of the same color on the anterior part of the carapace.

F. *Mastigopus stage.*—After it had been kept three days this larva passed through a moult, by which only slight changes were introduced. The fourth pair of walking legs is now distinctly jointed, the fifth remaining as a bud. The flagellum (endopodite) of the second pair of antennæ uncoils and speedily lengthens. The terga of the first and second abdominal somites bear on the lower lateral margins of each side a short tooth. The larva lived four days without further ecdysis. Figs. 26, 27, 30, and 31 are from this stage.

G. *Mastigopus stage* [Pl. XI, Figs. 28, 29, 32–34, Pl. XII], (Length = 9^{mm}).—An older larva, caught in the net on May 7, is shown on Pl. XII. The most striking features of this form are the long trailing antennæ (flagella of the outer pair), the actual length of which is about 1 inch, which is more than twice the length of the larva. The remarkable eyes which this animal possesses give it a very odd appearance. They are placed at the extremity of club-shaped stalks, each of which is nearly 2^{mm} long. The distance between the eyes is 4.7^{mm}. In passing to the adult stage the eye-stalks are much reduced. The outer antennæ have a short peduncle; a long scale, armed with stiff hairs on the inner margin, and a long flagellum, all very much as in the adult prawn. (Pl. XII, and Pl. XIII, Figs. 40, 41.) The first pair of antennæ are much less like the adult form. (Pl. XII and Fig. 40). The stalk is longer and more slender than in the full-grown condition. The flagella are short, the inner one still rudimentary, and the sensory hairs are retained.

The carapace has developed on it a lateral furrow, which is surmounted by a conspicuous spine placed on either side at a point one-third the distance from the rostrum to the posterior end of the carapace. The rostrum is short and stout, bent upward, and does not reach beyond a line passing through the vesicula auditoria. The front of the carapace bears also a short dentiform process on each side below the rostrum. These are the only indications of the future spinous armature of this region of the body. The abdomen and abdominal appendages are about as represented in Fig. 27. The telson is a short triangular plate, garnished with short bristles, and is terminated by a pair of very small spines. The uropods are provided with a close fringe of interlocking, plumose hairs, which are longest on the inner margin. The outer lamella is one-third longer than the inner and three times as long as the telson.

The first and second maxillæ of this larva are represented in Figs. 28 and 29. In Figs. 12, 19, 29, and 38 we have four stages in the evolution of the first maxilla, and we see that it undergoes comparatively little change. No trace of a palpus (endopodite) was seen in the specimen examined (Fig. 29), the appendage consisting of a small inner (coxopodite) and a larger outer knob-shaped branch (basipodite), each armed with short tooth-like spines. The second maxilla has also the adult character. (Figs. 28, 42.) It consists of an elongated outer plate (scaphognathite), fringed with a single row of plumose hairs; a palp-like endopodite, and an innermost lobulated division (basipodite and coxopodite), each part carrying a few bristles.

The first maxilliped of stage F is given in Fig. 30. It consists of a basal portion (coxopodite), which bears an inner and larger lobe (basipodite), having bristles on its proximal border; an exopodite tipped with a pair of bristles, and of an intermediate bud (endopodite) bearing a single bristle. Part of the second maxillipeds is shown in Pl. XI and also in Fig. 31 (St. F.). The exopodite is rudimentary. The outer segments are covered with spinous bristles. We see already a resemblance between these appendages and their adult forms. (Figs. 43, 45.) The third pair of maxillipeds are still the largest limbs. (Pl. XI, Mxp. III.) The terminal joint bears several long spines. Compare with the adult limb seen in Fig. 46.

The pereiopods are slender appendages, of which the third pair are longest, as in the adult; the second are longer than the first; the fourth and fifth are rudimentary. One of the first pair of pereiopods is represented in Fig. 33. This appendage is nonchelate, unlike the adult stage; all its segments are armed with long spines, and there is a cluster of serrate bristles on the inner side of the proximal end of the terminal segment, and near it a similar cluster on the next. Similar tufts of hair are found on the adult appendage. (Pl. XIII, Fig. 47.) The terminal joint of the second thoracic limb is shown in Fig. 32; the basal extremity of the third, the fourth, and fifth are given in Fig. 34. The second and third pair are chelate; the fourth is rudimentary; the fifth is still a bud. The abdominal appendages, excepting the sixth pair described above, are all uniramous. (Fig. 27.)

This larva is colorless, excepting large spots of reddish pigment, distributed much as in the previous stage. There is a spot near the extremity of the eye-stalk and similar ones on the abdomen. Some of the appendages are also tipped with brownish red. The attainment of the adult characters is now mainly a question of the further growth of parts already present.

The above outline gives us a pretty complete history of the metamorphosis of Stenopus. Between stages B and C a lacuna occurs, but it is not difficult to bridge over this gap. The development of Stenopus is especially interesting, inasmuch as it combines certain features of the metamorphosis of Penæus, Sergestes, Lucifer, and the Prawns in general, but it differs essentially from any of them. Detailed comparisons are purposely omitted in this paper, but we will call attention to the apparent similarity of the second larva of Stenopus (Pl. VIII, Fig. 17) to the zoëa of *Callianassa subterranea*, figured by Claus.* The length in each case is 5mm. He says, p. 54:

> Die jungen Callianassa larven besitzen beim Verlassen der Eihüllen eine ansehnliche Grösse, sind sehr langgestreckt und tragen drei spaltästige Füsspaare, von denen sich das Vordere schon wesentlich der Formgestaltung des späteren Maxillarfusses nähert. Der lange Stirnschnabel, sowie die Bestachelung des Abdomens, dessen zweites Segment mit einem besonders langen Rückendorn bewaffnet ist errinern an die oben beschriebene larve.

which applies perfectly to the Stenopus zoëa, except that the latter has the first thoracic segment with its appendages, while, according to Claus, the first zoëa of Callianassa has not, although his figure is not clear on this point. The rostrum, eyes, antennæ, second maxillæ, and maxillipeds are nearly identical in the two forms. The differences are in the shape of the telson and in the condition of the thoracic appendages. The tail fin has a convex posterior edge, a median and two lateral, short spines, and eleven intermediate pairs. The rudiments of the sixth pair of abdominal appendages show through the integument. Behind the maxillipeds, already "die kurzen, schlauchförmigen Anlagen sämmtlicher Thoracalfüsse unter dem Integument bemärkbar sind."

Among the Prawns, Penæus has apparently preserved most completely the ancestral history of the Decapod Crustacea, and for this reason a thorough knowledge of the development of related species is very desirable.

IV. THE ADULT.

STENOPUS (Latreille).

Cancer (Herbst).

Palæmon (Olivier).

Stenopus (Latreille) Léach, Desmarest, Roux, Milne, Edwards, Adams, Dana, etc.

Diagnosis of Stenopus hispidus (Latreille).—Body nearly cylindrical. Carapace with prominent rostrum and distinct transverse groove. Outer antennæ with long, bristle-bordered scale bent under the inner antennæ toward the middle line. Second maxillipeds with epipodite and long exopodite. Third maxillipeds very long and appendicular, with a rudimentary exopodite at base. First, second, and third pairs of pereiopods chelate. The first and second pairs quite slender, ending in small shears. Third pair longest, bearing the large claws. Fourth and fifth pairs of pereiopods slender and nonchelate. Carpus and propodus of the same articulated into numerous rings. First pair of pleopods uniramous in both sexes, all the others biramous.

Special description.—Length, 37–44mm ($1\frac{1}{2}$–$1\frac{3}{4}$ inches). There is little difference in size between the sexes, but the females are usually a trifle the larger.

Color: Body invariably white, crossed by three bands of reddish crimson. Appendages colorless, excepting the third pair of pereiopods, which are encircled by four wide zones of the same color. These markings are not of uniform tint, but vary from bright scarlet to mottled orange red. The basal joints of at least the third and fourth pairs of thoracic legs sky blue. Antennæ snow white. For further particulars under this heading, see Pl. V, and Sec. I.

The carapace (Fig. 37) presents a marked transverse fossa. It is covered with short dentiform spines, largest on the front. The rostrum is elevated, extending hardly beyond the basil joint of the inner antennæ. It ends in a sharp terminal spine and carries six to seven stout, curved teeth on the dorsal median line, besides a single spinule projecting downwards near the tip. From the single dorsal row of teeth two similar rows diverge, extending back to the transverse furrow. The

*C. Claus: "Untersuchungen zur Erforschung der genealogischen Grundlage des Crustaceen-Systems." Wien, 1876. Taf. VIII, Fig. 1; also Figs. 2–7.

rostrum also bears on each side a single row of about four teeth projecting forward. The under side is unarmed. Several large spines occur in the angle behind the eye and on the basal joints of the antennæ.

The epidermic spines, which are characteristic of the Hispidus, though not confined to this species, are found upon the dorsal surface of the entire body, on the third pair of pereiopods and on the bases of the appendages generally. The first, second, fourth, and fifth pairs of thoracic legs are destitute of conspicuous spines. The spines of the carapace and anterior abdominal terga are bent forward; those of the fourth, fifth, and sixth abdominal somites and of the tail fin are appressed, stouter, nondentilate, and point backwards.

The telson is arrowhead-shaped; its free edges are garnished with short, closely set hairs; it has a median groove, bordered on either side by a longitudinal elevated ridge, bearing spines; it hardly surpasses the uropodal lamellæ. The eyes project at right angles to the long axis of the body. They have dark brownish black pigment and are mounted upon short, stout stalks, covered with small prickles. The labrum consists of a semicircular bar, the convex surface of which points forward and bears two nearly median spines projecting downward. From its concave border is suspended a lingulate appendage, which is supported by a thin, median, and vertical plate. The inner antennæ (Fig. 40) bear very long flagella, the disposition of which has already been noticed (Sec. 1). The segments of the stalk are armed with stout denticles, and each division of the proximal portion of the outer flagellum or exopodite bears externally a sharp spine.

The outer antennæ (Fig. 41) possess at their base a long, narrow scale (exopodite), which is traversed by longitudinal grooves. Their inner borders, which meet in the middle line, are fringed with closely set hairs. The stalk or protopodite is spiny, and the flagellum or endopodite is two and a half times the length of the body of the animal. The mandibles (Fig. 39) bear very large palpi, and have blunt interlocking teeth; a transverse furrow divides the cutting surfaces of each. The first pair of maxillæ (Fig. 38) consist of an inner (coxopodite) and outer branch (basipodite), with a slender endopodite. The outer division or coxopodite is thickly beset with strong spines. The second pair of maxillæ (Fig. 42) are furnished with an elongated plate, the "bailer" or scaphognathite, which is fringed with hairs, an inner lobulated portion (basipodite and coxopodite), and an intermediate endopodite, which bears several plumose hairs at its distal end.

The first pair of maxillipeds (Fig. 43) consist of an inner lobulated portion (coxopodite and basipodite), thickly studded with short bristles, an outer triangular plate (epipodite), and two intermediate appendages. The innermost of the latter (endopodite) terminates in a stout spine. It consists of two segments armed without by a row of long plumose hairs. The whip-like, appendage exopodite next this is twice as long and is bordered with short hairs. In the second pair of maxillipeds the basil portion consists of several lobules, tufted with hairs, and a small, external epipodite. There is a stout incurved endopodite, with hirsute terminal joints, and a long, slender exopodite. A transparent lamella springs from the outer side of the proximal half of the the endopodite, and bears plumose hairs on its free margin.

The third pair of maxillipeds (Fig. 46) are long and conspicuous, somewhat less slender than the first or second pairs of thoracic legs. The inner and outer borders are fringed with long hairs. The outer border is denticulated; the distal extremities of the segments, as of the ischiopodite, produced into a sharp spine. The basipodite is small, bearing the persistent and rudimentary exopodite, which is a slender palp equal in length to the ischiopodite. The first pair of dereiopods (Fig. 47) are small, slender, and chelate. The second pair of pereiopods are similar to the first pair, but longer.

The third pair of pereiopods, the "great chelæ," differ somewhat in size, the right being sometimes larger and sometimes smaller than the left. The chela is compressed and slightly twisted. There is a single row of stout regular denticles, forming a saw-tooth edge on either margin of the "palm," and several rows of lesser spines on the broad sides. There is also a longitudinal groove extending to the base of the dactyle. The carpus is prismatic and bears about five rows of large teeth. The ischium is more cylindrical, but similar. The dactyle and propodus possess each a prominent tooth, which fits into a corresponding depression.

The fourth pair of pereiopods (Fig. 48) end in short bifid dactyles, the terminal claw bearing a shorter proximal one below. The propodus is superficially segmented into from five to seven rings, which vary in size. The right propodus may have five rings, the left seven. The carpus is articulated into ten to twelve segments, commonly twelve, of variable or equal size. The fifth pair of pereiopods is similar to the fourth, but shorter. The propodus bears from six to seven segments, the carpus from eight to twelve. In the fourth and fifth thoracic legs the number of rings into which the propodus and carpus are divided differ within the above limits in different individuals of either sex and on the right and left sides of the same individual. The pleopods are all biramous, excepting the first pair, in which the endopodite is suppressed as shown in Fig. 44. This pair of appendages is much smaller in the male. In the female the first swimmerets are nearly as long as the following pairs and are fringed with long setæ.

Measurements (in millimeters).

[Locality: Nassau, New Providence, Bahama Islands.]

Sex	♂	♀	♂	♀	♂
Length from tip of rostrum to end of telson	37	43	44	44	40
Length of carapax, including rostrum	14.5	16	.....	.....	.....
Greatest breadth, including spines	8	10	.....	.....	.....
Greatest depth, including spines	7.5	10	.....	.....	.....
Length of rostrum	4.5	.....	.....	.....	.....
Distance between transverse furrow and tip of rostrum	9	10	.....	.....	.....
Length of first abdominal tergum	1	1.5	.....	.....	.....
Length of second abdominal tergum	2.5	3	.....	.....	.....
Length of third abdominal tergum	5	5.5	.....	.....	.....
Length of fourth abdominal tergum	3	3	.....	.....	.....
Length of fifth abdominal tergum	2.8	3	.....	.....	.....
Length of sixth abdominal tergum	4.5	5.5	.....	.....	.....
Length of telson	8	9	.....	.....	.....
Gratest breadth of telson	3	4	.....	.....	.....
Length of eye-stalk	3	.....	.....	.....	.....
Greatest diameter of eye	2	2	.....	.....	.....
Breadth between eyes	6.5	7	.....	.....	.....
Stalk of inner antennæ	45	.....	.....	.....	.....
Length of terminal segment of the same	1	.....	.....	.....	.....
Length of inner flagellum of the same	73	.....	86	.....	.....
Length of outer flagellum of the same	75	.....	98	.....	.....
Length of scale of outer antennæ	9	.....	.....	.....	.....
Greatest breadth of the same	1.8	.....	.....	.....	.....
Length of stalk of outer antennæ	1.5	.....	.....	.....	.....
Breadth of stalk of outer antennæ	1.5	.....	.....	.....	.....
Length of flagellum of outer antennæ	92	.....	119	.....	.....
Breadth of flagellum of same at inner end	0.4	.....	.....	.....	.....
Length of third maxilliped	18.5	.....	.....	.....	.....
Length of terminal joint of the same	2.5	.....	.....	.....	.....
Length of basal joint of the same	5	.....	.....	.....	.....
Breadth of basal joint of the same	1	.....	.....	.....	.....
Length of exopodite of the same	5	.....	.....	.....	.....
Length of first pereiopod	20	.....	.....	.....	.....
Length of propodus of same	5	5	.....	.....	.....
Breadth of propodus of same	1	1	.....	.....	.....
Length of dactyle of same	2	2	.....	.....	.....
Length of carpus of same	6	8	.....	.....	.....
Length of second pereiopod	27	.....	.....	.....	.....
Length of propodus of same	6.5	7	.....	.....	.....
Length of dactyle of same	3	3	.....	.....	.....
Breadth of propodus of same	1.5	2	.....	.....	.....
Length of carpus of same	9	11	.....	.....	.....
Length of meros of same	7	8	.....	.....	.....
Length of left third pereiopod	48	53	.....	.....	.....
Length of chela	19	22	.....	.....	.....
Greatest breadth of same with spines	5	6	.....	.....	.....
Greatest depth of same with spines	3	4	.....	.....	.....
Length of dactyle	7	9	.....	.....	.....
Width over tooth of dactyle	2.1	2.5	.....	.....	.....
Length of carpus of same	9.5	12	.....	.....	.....
Greatest breadth of carpus without spines	3	3	.....	.....	.....
Greatest breadth of carpus with spines	4	4	.....	.....	.....
Length of meros of same	11	12	.....	.....	.....
Length of right third pereiopod	46	51	.....	.....	.....

Measurements (in millimeters)—Continued.

Sex	♂	♀	♂	♀	♂
Length of chela of the same	18	19	.....	.....	.....
Greatest breadth of same with spines	5	5	.....	.....	.....
Greatest depth of same without spines	4	3	.....	.....	.....
Length of dactyle of same	7	.....	.....	.....	.....
Width over tooth of dactyle	2	.....	.....	.....	.....
Length of carpus of right third pereiopod	9	11	.....	.....	.....
Greatest breadth of same with spines	4	4	.....	.....	.....
Greatest breadth of same without spines	3	3	.....	.....	.....
Length of meros of same	12	12.5	.....	.....	.....
Length of fourth pereiopod	36	.....	.....	.....	.....
Length of dactyle of same	1.5	1.5	.....	.....	.....
Length of propodus of same	5	5	.....	.....	.....
Number of rings in propodus	5	5	.....	.....	.....
Length of carpus of same	14	18	.....	.....	.....
Number of rings in carpus	12	12	.....	.....	.....
Length of meros of same	10	11	.....	.....	.....
Greatest breadth of meros	1.4	.....	.....	.....	.....
Length of fifth pereiopod	30	.....	.....	.....	.....
Length of propodus of same	5	6	.....	.....	.....
Number of rings in propodus	6	6	.....	.....	.....
Length of carpus of same	15	16	.....	.....	.....
Number of rings in carpus	13	12	.....	.....	.....
Length of meros of same	9.5	11	.....	.....	.....
Length of first pleopod	3	7	.....	.....	.....
Length of third pleopod	.....	9	.....	.....	.....
Length of inner lamella of same	4	6	.....	.....	.....
Breadth of inner lamella of same	1.5	2	.....	.....	.....
Length of outer lamella of same	4	6	.....	.....	.....
Length of inner lamella of uropod	6.5	8	.....	.....	.....
Length of outer lamella of uropod	7	9	.....	.....	.....
Greatest breadth of outer lamella of uropod	3	3.5	.....	.....	.....

REMARKS.—The earliest figure of Stenopus hispidus with which I am acquainted is that of Olivier, published in 1811 under the name of *Palæmon hispidus* (1, Pl. 19, Fig. 2). In this drawing the third thoracic leg of the right side is represented as rudimentary. In explanation of this he says: "La pince gauche manquoit et paroissoit repousser. Dans un autre, c'étoit la droite qui manquoit et paroissoit repousser de même." The next drawing appears in Milne Edwards's Atlas (3, Pl. 25, Fig. 13) of 1837. Like Olivier's plate this is crude and faulty.

A second and very much better likeness of the Hispidus by Milne Edwards came out in Cuvier's Le Règne Animal (4, Pl. 50, Fig. 20). This is represented as pale straw color and was evidently made from an old alcoholic specimen. Some of the parts are also figured. Adams's figure (5, Tab. XII, Fig. 6), already noticed, and his brief description agree essentially with the Nassau form. The antennæ are not in their natural position, and should probably be more than twice as long as represented. Of the habits of the species he says: "The Stenopus, Sicyonia, and Penæus, usually swim in a slow, deliberate manner forwards, and occasionally with a sudden jerk propel themselves backward. They keep at a considerable distance from the shore and seem to love deep still water, never appearing when the surface of the sea is ruffled." The drawing by Dana (6, Pl. 40, Fig. 8) represents the antennæ of this animal for the first time in a natural position. The antennal and antennular stalks are, however, much too slender, compared either with Adams's figure or with the Nassau form. The length is given as 3 inches, while the Stenopus on the plate measures about $2\frac{1}{2}$ inches. So far as it goes his description agrees in the main with my own. He says: "The legs of the first and second pairs and of the fourth and fifth are colorless, and they are extremely slender, much more so than in the drawings hitherto giving of the Hispidus; third pair is about one-fourth longer than body, fourth joint of second pair nearly twice as long as hand; fourth joint of fourth pair 12-jointed, and fifth joint 7-jointed; tarsus minute (p. 606)."

This *extreme* slenderness does not appear in the specimens examined by me, nor is it apparent in Adams's figure, which is one of the previous drawings referred to by Dana. In making the drawing of the Nassau Stenopus (Pl. V) great pains were taken to represent all the appendages

in their natural positions, and in their true relative proportions. In Adams's plate the fourth joint of the fourth thoracic leg has 16–17 rings, the fifth joint 8 rings. In the Nassau form the carpus has 10–12, the propodus 5–7 rings. In details like this, where the right and left sides of the same individual are often unlike, it would be surprising to find agreement. Von Martens's short notice of the Cuban occurrence does not give us much additional knowledge, but there is no doubt that the alcoholic specimens examined by him belong to the same species as that described in this paper. He says: "Ich weiss keinen erheblichen Unterschied zwischen diesen cubanischen Exemplaren und den indischen anzugeben, welch letztere ich bei Amboina gesammelt habe. * * * Nur erscheinen die indischen im Leben bunt roth gezeichnet, in Spiritus blass orange und mehr hartschälig, endlich scheint Carpus und Hand des dritten Fusspaars bei ihnen minder vierseitig, doch ist dieser letztere Unterschied gering und fliessend." He then adds that he would not be surprised if it should turn out that the West Indian form was specifically different from the East Indian.

So far then as we can judge from the figures and meager descriptions in our possession, the Asiatic Stenopus hispidus can not be regarded as specifically distinct from the American form. Perhaps a point of difference worthy of remark is the length of the body from rostrum to end of telson, which is given as $2\frac{1}{2}$ and 3 inches by Adams and Dana respectively. None of the Nassau specimens which I have measured were more than $1\frac{3}{4}$ inches long. The data upon this point are not conclusive, and, in view of our knowledge of local variations in this respect, can not be regarded as of much importance. It is hoped that the descriptions and measurements which are here given will afford a basis for future comparisons with the Pacific Stenopus hispidus.

List of species.

So far as I can learn, only five species of the genus Stenopus (Latreille) have been described, viz:

(1) *Stenopus hispidus* (*Latr.*):
Distribution: (*a*) Indian Ocean, Borneo, and Philippines (Adams).
(*b*) Paumotu Islands and Balabac Passage, north of Borneo (Dana).
(*c*) Amboyna, Cuba (Von Martens).
(*d*) Abaco and New Providence, Bahama Islands.
(*e*) "Red Sea, Indian Ocean, Indian Archipelago, New Guinea" (de Man).

(2) *Stenopus spinosus* (*Risso*):
Mediterranean (Heller), teste Von Martens and de Man.

(3) *Stenopus ensiferus* (*Dana*):
Fiji Islands.

(4) *Stenopus semilævis* (*Von Martens*):
(One specimen in the Berlin Zoölogical Museum, purporting to have come from the West Indies. Length 12mm. Von Martens.)

(5) *Stenopus tenuirostris* (*de Man*):
Amboyna: Length 24mm. (More closely allied to Stenopus spinosus of the Mediteranean than to Stenopus hispidus, and is the representative of the former in the Indian Ocean; de Man.)

STENOPUS LITERATURE.

(1) *Olivier:* Encyclopédie Méthodique, Hist. Nat. Insectes, t. viii, p. 666, 1811.
(2) *Latreille:* Encyclopédie Méthodique, Hist. Nat. Crustaces, Arachnidses, et Insectes, t. 10, Paris, 1882.
(3) *Milne Edwards, H.:* Hist. Nat. des Crustaces, t. 2, p. 406, 1837.
(4) *Milne Edwards, H.:* Le Règne Animal, Cuvier; Les Crustaces, with Atlas, by Milne Edwards, p. 137.
(5) *Adams and White:* The Zoölogy of the Voyage of H. M. S. Samarang, 1843-6, p. 61, London, 1850.
(6) *Dana, J. D.:* U. S. Exploring Exped. U. S. N., 1838–1842, vol. xiii, pt. 1, Crustacea, p. 607.
(7) *Martens, E. v.:* Ueber Cubanische Crustaceen; nach den Sammlungen Dr. J. Gundlach. Archiv. f. Naturgesch., 38. Jahrg., Bd. 2, 1872, p. 143.
(8) *Heller:* Crustaceen des südlichen Europa, S. 299. (I have seen only references to this paper.)
(9) *De Man, J. G.:* Bericht über die im indischen Archipel von Dr. J. Brock gesammelten Decapoden und Stomatopoden. Separat-Ausgabe aus dem Archiv. f. Naturgesch., 53. Jahrg., pp. 215–600, 17. Taf., Berlin, 1888.

CHAPTER III.

THE HABITS AND METAMORPHOSIS OF GONODACTYLUS CHIRAGRA.

By W. K. BROOKS.

(With Pl. I, III, XIV, and XV.)

THE STRUCTURE AND HABITS OF THE ADULT.

This well-known species is found along the shores and islands of all tropical and subtropical seas, and our collections contain specimens from the Atlantic, the Pacific, and the Indian Oceans. Among the many localities where its presence has been recorded the following may be named: Bermuda, Florida Keys, Bahama Islands, Cuba, St. Thomas, Brazil, Mediterranean, Cape St. Roque, Samboanga, Samboanga Banks, Nicobars, Red Sea, Amboina, Indian Ocean, New Guinea. It is subject to but little variation, notwithstanding its very wide distribution, and also notwithstanding the fact that there are several other distinct species of Gonodactylus extremely similar to chiragra, and distinguishable from it by only very minute differences. There is a well-marked chiragra-like group of species all so close to each other that their divergence from each other must have been comparatively recent, and in view of this fact it seems remarkable that one of these species should so persistently retain its identity when exposed to such a wide diversity of conditions.

The species may be thus characterized: Stomatopoda with the sixth abdominal somite separated from the telson by a movable joint; the hind body convex; and the dactyle of the raptorial claw without spines and enlarged at the base; rostrum consisting of a transverse proximal portion more than twice as wide as long, with subacute antero lateral angles and a slender, acute median spine which does not quite reach to the bases of the eyes; carapace nearly rectangular, three fifths as long as wide, leaving the dorsal surface of the second thoracic somite completely exposed; antero-lateral angles semicircular and projecting beyond the median gastric area, which is nearly flat, and bounded by two nearly parallel gastric sutures, which are continued to the posterior edge of the carapace, which is nearly transverse with rounded postero-lateral angles; the transverse cervical suture is faintly marked, distant from the anterior margin about two-thirds of the length of the carapace; second thoracic somite, somewhat narrower than the carapace, with acute lateral angles; the eight following somites equal in width and wider than the carapace; the third, fourth, and fifth thoracic somites about equal in length; the lateral margins of the third are straight, with rounded angles, and as wide as the dorsal portion; the fourth is narrowed a little towards the lateral edge, and the fifth still more so; dorsal surfaces of the free thoracic somites and of the first five abdominal somites smooth; hind body convex; all the abdominal somites have marginal lateral carinæ, which are nearly linear, with the anterior end only a little wider than the posterior end; postero-lateral angles rounded in the first four abdominal somites, rectangular in the fifth, and acutely pointed in the sixth; there are no dorsal carinæ on the first five abdominal somites, and no median dorsal carina on the sixth, which carries three pairs of swollen convex lateral carinæ, which are equal in length and end posteriorly in acute spines, which are occasionally wanting on the submedian pair; the external carina is much less swollen than the others, and it unites at its posterior end with the laterial marginal carina; the spines of all the carinæ project beyond the posterior edge of the somite and lie in the same transverse plane.

The fifth abdominal somite is somewhat longer than those in front of it, and about twice as long as the sixth. The telson sometimes presents slight variations, but most of its characteristics are well marked, so that there is usually no difficulty in distinguishing the species by examining it. It is considerably wider than long, and its median portion is occupied by a rounded prominence, which consists of three broad, convex rounded carinæ, none of them ending in spines; the median one is longer than the others and spatulate at its posterior end, while the others have both ends obtusely rounded and alike; external to the proximal end of each lateral carina, and almost directly under the tip of the second, or intermediate dorsal carina of the sixth abdominal somite there is a small polished hemispherical tubercle. The edge of the telson is folded into six teeth, of which the submedians are largest and project farthest backwards; the tips of the intermediates are distinct and reach about half way to the tips of the submedians; the laterals are obsolete on the dorsal surface, although thin, small tips are distinctly visible on the flat ventral surface of the telson; each of these six teeth carries a dorsal carina; that of the lateral is marginal and nearly linear, while the others lie in the dorsal axes of the teeth and are thick and convex; that which lies above the submedian tooth is short, and lies in the same longitudinal plane as the external carina of the median prominence of the telson, while that which lies above the intermediate tooth runs nearly to the anterior edge of the telson; the median edges of the submedian teeth are minutely serrated, slightly concave, and meeting at an acute angle. There is a minute, nearly obsolete, tooth in the angle between the submedian and the intermediate, and the tips of the submedians are occasionally, but exceptionally, tipped by movable acute spines. The dorsal surface of the basal joint of the uropod ends posteriorly in an acute spine with a small lobe on the outer side of the base; its ventral surface ends posteriorly in a curved process divided into two acute curved spines, of which the outer is much the stouter and usually considerably longer than the inner, although they are occasionally nearly equal; the outer one has no marginal tooth. The paddle of the exopodite is about half as long as the second joint, which carries a central terminal immovable spine, and usually eleven—rarely twelve, and still more rarely ten—movable spines, of which nine are marginal and the tenth and eleventh terminal, largest, and central to the paddle. The eyes are cylindrical, with rounded corneæ, and the first and second antennæ are about equal in length, and more than half of the second joint of the shaft of the first antenna is exposed in front of the eye.

In the Bahama Islands this species presents two well-marked color variations, which occur side by side, specimens of both sorts being often found in burrows less than an inch apart. In the one form the color is a uniform dull-olive without spots or markings of any sort, as shown in Pl. III; while the other form, which is copied in Pl. 1, Fig. 2, is more transparent and is delicately mottled over the entire dorsal surface in an intricate but constant pattern of greyish-green pigment so distributed as to form three transverse bands across the carapace and the large joints of the raptorial claws and fine transverse bands across the telson, while over the rest of the dorsal surface it forms a complicated reticulum. This difference is not sexual, for I found both males and females of each color; nor is it distinctive of age, for, while all the largest specimens were of the uniform green color, I found specimens of each color of all sizes except the largest. It is not probable that there are two constant color varieties living side by side in the Bahama Islands, and I am disposed to think that the mottled transparent specimens are those which have recently moulted, and that the color becomes more uniform as the cuticle hardens.

In the Bahama Islands this species inhabits burrows which it constructs in the coral rock or in masses of coral in shallow water, and, as nearly all the localities where its presence has been recorded are in the coral area, it is probable that this habit is pretty generally retained by the species all over its habitat. I have found it most abundant in lagoons and sounds on shelving beaches which are bare or nearly bare at low tide; and when a beach of this description is overhung by a limestone cliff, from which fragments fall into the water, each fragment is honeycombed by their burrows. A crack or natural depression in the rock seems to be selected by the animal when about to construct a new burrow, for most of the burrows opened into such cracks. The mouth of the burrow is nearly circular and only a little larger than the body of its inhabitant, but just within it widens out into a flask-shaped cave (Pl. III), with smooth, even walls and regular curvature, and large enough for the animal to coil up or turn around inside it. Most of the burrows are horizontal, but many are vertical with the opening below, and a few are vertical with the opening above.

The animals usually rest coiled up, with the eyes and antennæ directed outwards, just within the mouth of the burrow. They are always on the alert and reach out and snap at every small animal which approaches, even when it is two or three times larger than the Gonodactylus. They rarely pursue their prey, at least in the day time, and while a bait held near the mouth of the burtrow will usually tempt them as far out as the body can be stretched without leaving the burrow they seldom go any further. In aquaria they are much more active at night than in the daytime, and they may possibly wander more in search of prey at night than I have ever seen them do in the daytime. They are solitary in their habits, and I have never found two in the same burrow. They are pugnacious to an astonishing degree, and their fighting habits, as I have observed them in aquaria, are so fixed and constant that they must be constantly exercised by the animals when at home. When two specimens are placed together in an aquarium they at first appear to be unconscious of each other, but more careful examination will show that their eye stalks are in constant motion following each movement of the enemy. They soon assume a position in which they are face to face, although they may be on opposite sides of the aquarium, and the constant motion of their eye stalks shows how intently each movement is watched. Soon one attempts to get behind the other, but each such attempt is frustrated, until finally they are brought close together, face to face, and soon one springs suddenly upon the other and attempts to pinch some unprotected part. They then spring apart and eye each other again to repeat the attack at short intervals until one is disabled; the other then springs upon him and soon tears him limb from limb, disjointing all the free somites of the body and tearing out and devouring the flesh.

I was not able to learn how the burrows are made, for none which I kept in captivity made burrows. The regularity and smoothness of the burrows and their adaptation to the shape and size of the body indicate that they are constructed by the animals themselves. The habit of burrowing in hard rock instead of soft mud is a fortunate one for the naturalist; for, while it is almost impossible to obtain the eggs of an ordinary Stomatopod without using a steam dredging machine; it is easy to get those of Gonodactylus by breaking up the rock in which it lives.

While adult Stomatopods are abundant and widely distributed, their eggs are almost unknown, for most of them inhabit deep burrows under the water, where it is no easy matter to capture the adults, and even when these are caught they do not carry eggs even in the breeding season, for the eggs are not fastened to the appendages as they are in most Crustacea, but are deposited at the bottoms of the inaccessible burrows. As they are dependent upon the aëration which is produced by the current of water which the parent pumps through the burrow by means of the valve-like paddles of the abdominal feet, they die when deprived of this current. The eggs are sometimes obtained, but unless they are found in an advanced stage of development it is difficult to rear them, and I know of no Stomatopod which has been reared from the egg under observation except the Bahama *Gonodactylus chiragra*. As the pelagic larvæ are large and conspicuous they are often captured at the surface of the ocean in the tow net, and the number of genera and species of Stomatopod larvæ which have been described is nearly equal to the number of adult species which are known, and the opportunity to identify even one of these larvæ by actually rearing it from the egg is a most noteworthy and important occasion.

The habits of the Bahama Gonodactylus afford this opportunity; for the nature of the rock which it inhabits prevents the construction of a deep burrow, and as the fragments of rock may easily be carried ashore and broken up the eggs can be obtained without difficulty. At the time of my first visit to the Bahamas I was engaged in correcting the proofs of my report on the *Challenger* Stomatopods, and one of the motives of the expedition was the hope that I might possibly obtain Stomatopod eggs. A day or two after our arrival Dr. E. A. Andrews brought me a Gonodactylus and a bunch of yellow eggs, which he had picked out of a rock which he had broken to pieces while searching for Annelids. The eggs were newly laid, and, while they were obviously those of some crustacean, there was no evidence that they belonged to Gonodactylus except the fact that they were found among the fragments of a rock which also contained this animal. As soon as I saw the eggs and heard how they had been obtained I started for a point where the beach was covered with fragments of coral rock. It was then late in the afternoon and growing dark, but I waded into the water and carried ashore as large a rock as I could lift. After I had thrown this on to a larger rock and broken it to pieces there was just daylight enough to show me

the Gonodactyli scattering in all directions, and the masses of yellow eggs which were spattered over the large rock which I had used as an anvil; but the problem was solved, and I went home and to bed, confident that I should next day get all the embryological material I needed.

As shown in Pl. III, the animal molds or shapes the mass of eggs into a hemispherical cap, which fits over the convexity of the hind body and lies between it and the stone wall of the burrow. The parent reaches out to snatch at passing prey, but so long as she is undisturbed she remains in the burrow. When the burrow is broken open she quickly rolls the eggs into a ball, folds them under her body in a big armful, between the large joints of her raptorial claws, and endeavors to escape with them to a place of safety. The promptness with which this action is performed would seem to indicate that it is an instinct which has been acquired to meet some danger which frequently presents itself. It would seem as if a cave in a solid rock were a pretty safe refuge from all enemies except a naturalist with a geological hammer, and it is difficult to say what the accident is which has thus been provided against. The larger heads of growing coral are often broken off by the waves, and loose fragments of rock are overturned by severe storms, and it is possible that, when alarmed by a violent shock, it flees from its cave to escape the danger of being crushed when the rock is torn from its place and turned over. At any rate its habit is the reverse of that of most burrowing animals, for they usually retreat to the depths of the burrow when alarmed. This is true of all the Stomatopods which I have had an opportunity to observe except this species, and the chief use of the burrow of *Squilla empusa* is for refuge in danger, while *Lysiosquilla excavatrix* darts down its burrow at the least alarm and can not be driven out even when the sand has been dug up on all sides of it.

The Metamorphosis of Gonodactylus chiragra.

That feature of the life of Stomatopods upon which new data are most to be desired is the history of the early larval stages, and an abundant supply of the eggs of *Gonodactylus chiragra* rendered it an easy matter to obtain this history for that species. I also obtained a complete series of eggs for studying the embryology, but, as a few preliminary sections showed that this was of slight interest and that there is no essential difference from other Macroura as regards the egg embryology, this subject was not studied.

Most of our knowledge of the metamorphosis of Stomatopods is based upon the comparative study of collections of alcoholic specimens, and the direct observations on living larvæ are very scanty. In 1882 Faxen published an account (Selections from Embryological Monographs compiled by Alexander Agassiz, Walter Faxon, and E. L. Mark, I Crustacea, Cambridge, 1882, Bull. Mus. Comp. Zoöl., Vol. IX, No. 1, Pl. VIII, Figs. 2 and 3) of observations made three years before upon a young *Squilla empusa* which he had reared from an Alima larva; and in a paper which was published in 1879 I described (On the larval stages of *Squilla empusa*) a series of similar larvæ which I had studied while they were alive, and which was sufficiently complete to warrant the statement that they were the young of *Squilla empusa*, and that this species probably hatches from the egg in the *Alima* stage. In my report on the *Challenger* Stomatopods (Report of the Scientific Results of the Voyage of H. M. S. *Challenger* during the years 1873–'76, XVI, part XLV, 1886) I have given an account of the metamorphosis of *Lysiosquilla excavatrix* which I had reared at Beaufort, N. C.; but except for these observations our knowledge of Stomatopod metamorphosis rests upon the comparative study of preserved specimens, and, while the series which are picked out from miscellaneous collections sometimes present pretty satisfactory evidence as to the adults which they represent, this sort of indirect evidence can not be conclusive.

Large and varied collections of larvæ have been compared for the purpose of selecting those which form stages in the same series, and of ascertaining as accurately as possible the adult affinities of theoldest larvæ, by Claus (Die Metamorphosen der Squilliden, *Abhandl. d. k. Gesellsch. d. Wiss., Göttingen*, Bd. XVI, pp. 1–55, Pls. I–VIII, 1871) and myself (*Challenger* Rep., pp. 81–114). My own report was, so far as this subject goes, a supplement to Claus's work, for in its preparation I availed myself of his methods and results, amplifying and completing many of his observations, and confirming some of his results and correcting others. Combining his work with my own, I devoted a chapter of my report to the discussion of the larvæ, and gave a scheme or outline of the probable metamorphosis of each genus of adult Stomatopods.

Stomatopod larvæ or Erichthidæ, as they were named before their larval nature was suspected, have been divided into four genera, *Erichthoidina*, *Erichthus*, *Squillerichthus*, and *Alima*. Of these four the first, *Erichthoidina*, is simply a younger stage in the life of the *Erichthus*, and the third, *Squillerichthus*, a fully-grown larva of the *Erichthus* type, so that the genera become reduced to two, *Erichthus* and *Alima*. Of these two genera, one, *Alima*, is much more sharply defined than the other, *Erichthus*, which contains a number of divergent types, of which I have shown that five may be clearly distinguished, and I have proposed, for these five, names which indicate the adult genus to which each corresponds. I have shown that there are many reasons for believing that all *Alimi* are *Squilla* larvæ; *Alimerichthus*, the larvæ of *Chloridella; Erichthalima*, the larvæ of *Coronida; Lysierichthus*, the larvæ of *Lysiosquilla*, and *Pseuderichthus*, the larvæ of *Pseudosquilla*. The remaining larval type may be distinguished from the *Lysierichthus* by the shallowness of its carapace, which is not at all infolded, and by the position of its postero-lateral spines, which arise very close to the dorsal middle line; while it may be distinguished from the *Pseuderichthus* larvæ by the length of the posterolateral spines, which are at least half as long as the carapace, and also by the fact that the telson is wider than long and longer than the long outer spine of the uropod. For this larval type, which was represented in the *Challenger* collection by many specimens, I proposed the name *Gonerichthus*, giving, at the same time, many reasons for regarding it as the larva of the genus Gonodactylus. Several of these larvæ were selected and shown in Pl. XII, Fig. 5, Pl. XIII, Fig. 9, and Pl. XV, Figs. 1 and 5, of my report; and I pointed out that in all of these larvæ, as in the young Gonodactylus, the sixth abdominal somite has a pair of submedian spines near its posterior edge, and its posterolateral angles are produced into acute spines. The telson is slightly wider than long, and its submedian spines are long and slender, but shorter than they are in *Pseuderichthus*. The telson is notched on the middle line, and there are from fourteen to twenty small secondary spinules on its posterior edge, between the submedians. There is one small secondary spinule internal to the base of the lateral marginal spine, another internal to the base of the intermediate, and a third midway between this and the submedian.

In Pl. XV, Figs. 5 and 6, of my report, as in the young Gonodactylus, the outer edge of the proximal joint of the exopodite of the uropod is fringed by nine marginal spines, the terminal one longest, and the outer spine of the basal prolongation is much longer than the inner, but not so long as it is in *Pseuderichthus*. A comparison of the telson of the young Gonodactylus with that of the other larval types will show that the one now under discussion is the only one which exhibits this resemblance, and as this larva never exhibits any traces of marginal spines on the dactyle of the raptorial claw it must pertain to some known adult with an unarmed dactyle or else to a new genus. It is not probable that a larval type which is so common pertains to an unknown adult genus. The larvæ are not *Protosquillæ*, as this genus has the telson fused with the sixth abdominal somite, while it is free in the older larvæ; nor are they *Pseudosquillæ*, for they have no movable spinules on the tips of the submedian spines of the telson; and as all the other genera of Stomatopods except Gonodactylus have the dactyle armed, the only remaining genus is Gonodactylus, and the structural characteristics of the oldest larvæ indicate that they are the young of species in this genus.

Led by these considerations I did not hesitate to speak of these larvæ, in the *Challenger* report, as Gonerichthi, or young Gonodactyli, and to give this larval form as one of the diagnostic characteristics of the genus. This determination rests, however, upon circumstantial or indirect evidence; and, while the evidence is quite conclusive, I was nevertheless pleased to obtain more positive proof from the larvæ which I reared from the eggs of *Gonodactylus chiragra*.

Like many other Crustacea which inhabit the coral reefs, this species has its metamorphosis abbreviated and it hatches from the egg in an advanced condition. It is shown just before hatching, seen from behind in Pl. XIV, Fig. 1, and from in front in Fig. 2. The large yolk covers the dorsal surface, and the larva is doubled on itself, so that the telson and the tip of the abdomen are visible in a front view. The first five abdominal somites are indicated before it leaves the egg, and the first five pairs of abdominal appendages are fully developed, although the other appendages, with the exception of the mandibles and the large raptorial second maxillipeds, are either absent or rudimentary The eyes are large, and even before hatching they are movable, although they are nearly sessile.

The larva, immediately after hatching, is shown in side view in Pl. XIV, Fig. 3; in ventral view in Pl. XV, Fig. 8, and in dorsal view in Fig. 7 of the same plate. The carapace is nearly half as long as the entire animal, and its posterior border, which is deeply emarginated, crosses the midde line over the posterior edge of the tenth somite; the somite which carries the appendages which are usually called, in the decapod Crustacean, the second pair of legs. There is a short, rather stout rostrum, and the anterior end of the carapace, which covers about half the eyes, is nearly semicircular. The posterolateral spines are short and curved outwards; there are no secondary spines external to their bases, but there is a small median dorsal spine on the posterior edge of the carapace, while the anterolaterals are absent. The antennule consists of a two-jointed shaft with two flagella, one terminal and the other arising from the dorsal surface of the distal joint of the shaft. The antenna consists of a rudimentary exopodite, which is cylindrical and ends in five swimming hairs, although it is of little use in locomotion. The large eyes are subspherical, nearly sessile, and they touch each other on the middle line dorsal to the antennules. The mandibles are enormous and the two pairs of maxillæ rudimentary, as are also the first pair of maxillipeds, while the second pair, the large raptorial limbs of the adult, are well developed, although the dactyle is not folded backwards upon the penultimate joint or propodite. The third, fourth, and fifth maxillipeds, corresponding to the third maxillipeds and first and second ambulatory limbs of decapods, are rudimentary, and the three following appendages are absent, although all the corresponding somites are indicated as well as their ganglia. The abdomen is about twice as wide as the thoracic region and somewhat more than half as wide as the carapace. The first five somites are distinct and all end in acute posterolateral angles. The suture which separates the fifth from the unsegmented region, which represents the sixth and the telson, is obscure, and this region is longer than wide.

The abdominal appendages gradually decrease in size from the first and largest to the fifth pair, but all have their adult structure, except that they carry no gills and all are functional. The telson has four marginal spines on each side. Its posterior edge is slightly notched and carries seven or eight pairs of minute movable spines. The newly hatched larvæ swim actively about by means of their abdominal feet, not by flexing and extending the abdomen, and notwithstanding the presence of a great mass of food yolk in the walls of the stomach they eat voraciously. By a lucky chance I found their proper food at once. Several bunches of the eggs of some unknown Nudibranch were in the aquarium in which the first brood hatched, and the larvæ, nearly a thousand in all, soon settled down upon them, covering them completely, and at once began tearing them off and eating them. When washed away from them by means of a jet of water they swam about the aquarium for a short time, but soon settled down upon the eggs again. As these eggs are not very abundant they can hardly be the only food of the young larvæ, although I could find nothing else that they would touch, and they refused the eggs of all other Nudibranchs. At this stage the heart consists of a large anterior chamber in the region of the second maxillipeds and a large dorsal vessel running as far as the fifth abdominal somite, with a pair of ostia in each somite.

After about sixty hours they moulted and assumed the form which is shown in side view in Pl. XIV, Fig. 4. The rostrum and the spines on the posterior border of the carapace have lengthened, but its shape and relative size are about as before. The second antennæ are more clearly divided than before into a shaft and a scale, which has lost its hairs and is more flattened. The first pair of maxillipeds have made their appearance in the adult form, and the second pair are much larger than before, and the dactyle is now folded back onto the edge of the flattened penultimate joint. In all other respects the larva is like the younger one, but a little longer and with less food yolk. In about a week after hatching they molted again and passed into the third (Erichthus) stage, which is shown from above in Pl. XV, Fig. 9, and in side view in Pl. XIV, Fig. 5. The rostrum is now greatly elongated and reaches to the tips of the antennules. Small anterolateral spines have made their appearance, as well as a small spine external to the base of each posterolateral. These latter are greatly elongated and very slightly divergent. A great change in the shape of the carapace has taken place, as will be seen by comparing Fig. 7 of Pl. XV with Fig. 9. Its lateral margins are nearly parallel, and its greatest width only a little exceeds that of the abdomen. Its posterior border is now nearly transverse and crosses the middle line above the last thoracic somite. The

sixth abdominal somite has separated from the telson, but its appendages are not yet developed. The scale of the antenna is now fringed with hairs, and the eyes are divergent, with well developed stalks. The raptorial claws have greatly increased in size and are beginning to approximate to the adult form, while at the earlier stage they closely resembled the chelæ of the third, fourth, and fifth pairs of maxillipeds of an adult Stomatopod. From this time on to the end of its larval life the young Erichthus of *Gonodactylus chiragra* presents the characteristics of that larval type for which I have proposed the provisional name Gonerichthus; and, while the resemblance grows stronger as the larva grows older, it is unmistakable even now, and still clearer after the next molt, when it assumes the form shown in Pl. XIV, Fig. 6, from above, and obliquely from below in Pl. XV, Fig. 10.

The antennulary flagella are now beginning to elongate, and that of the antenna is now represented by a bud, but there are no new appendages, although the sixth abdominal somite is now indicated. Although it is very much younger than the Gonerichthi shown in my *Challenger* report in Pl. XV, Figs. 1, 5, 6, and 11, it resembles these larvæ in the following features as well as in many minor points: The rostrum is long and reaches beyond the tips of the antennules, and it has four or five median teeth on its ventral surface. The anterolateral angles of the carapace end in acute spines pointing forwards, and the anterior edges are inclined towards each other, so as to make at the base of the rostrum an angle a little greater than a right angle. The lateral borders of the carapace are nearly parallel, and the posterolateral spines long, slightly divergent, and with a small acute spine external to the base of each. The carapace covers all the five thoracic somites and all or nearly all of the first abdominal, and its posterior border is transverse. The median dorsal spine, which was carried on the posterior edge of the carapace of the younger larvæ (Figs. 3, 4, and 5 of Pl. XIV), has disappeared, although it persists until a much later stage in the larvæ shown in Figs. 1, 6, and 11 of the *Challenger* report. The hind body is now nearly three-fourths as wide as the carapace.

The lateral margins of the telson still carry, as they did during the earlier stages, four nearly equal marginal spines on each side; of these the most anterior is the *external*, the next the *intermediate*, the third a secondary spinule, and the fourth, which, at the stage shown in Fig. 6, Pl. XIV, forms the posterolateral angle of the telson, is the *submedian*. The posterior border between the submedians is very slightly notched and nearly transverse. All the *Challenger* Gonerichthi are very much older than this larva, and their telsons are more developed. The spines especially are much more elongated; but in Figs. 5 and 6 of Pl. XV of the report the secondary spine can be clearly recognized about halfway between the submedian and the intermediate.

With the assumption of the form shown in Pl. XV, Fig. 10, the habits of the larva undergo a sudden change. Up to this time, while able to swim briskly about by the use of their abdominal appendages, they spent most of their time near the bottom of the aquarium, seldom going up more than an inch or two, although they are quite able to reach the top of the water, which was about 10 inches deep, and when masses of Nudibranch eggs were suspended near the surface of the water they quickly discovered and fastened upon them.

Up to this time, also, they were peaceful and did not attack each other. Several hundred survived the molt which precedes the beginning of their pelagic life, but all of them soon died and none passed this stage, which is the one shown in Fig. 10. They now left the bottom, and became restless, swimming continually at all levels in the water. They refused to touch the eggs of which up to this time they had been so fond, and I could find nothing else which suited their appetites, but their proper food is, beyond question, small swimming animals of some sort, for they now began fighting among themselves, and when two met they would seize each other with their raptorial claws, and then tumble over and over together, until they struck the bottom, when both died. The survivors would not touch the dead bodies, although most of them soon shared the same fate, and the rest became weak and soon died.

At the same time that I was studying the growth of the captive larvæ I captured several older ones in the surface net, and one of them somewhat older than Fig. 10 is shown in Figs. 11 and 12. The third, fourth, and fifth maxillipeds are now developed and are like those of the adult; and

the three pairs of free thoracic legs, and the uropods are represented by buds. An umber of moults and probably an interval of many weeks intervenes between this stage and the one shown in Pl. xv, Fig. 11 of the *Challenger* report.

The life history of this species of Gonodactylus, in the Bahama Islands at least, is thus seen to be extremely simple. It hatches as an Erichthus and remains an Erichthus until it assumes its adult form; and as the successive appendages make their appearance they have from the first the structure which they are to retain through life. The statement which I made in my *Challenger* report (p. 55), that Gonodactylus hatches from the egg in the Erichthoidina stage and subsequently changes into an Erichthus, is an error, at least so far as Gonodactylus chiragra is concerned, although it is possible, in view of the great variation which we have observed in a single species of Alpheus, that in other regions, where the adults have different habits, the larva may hatch in a younger stage. Coral-dwelling crustacea seem to exhibit a tendency towards the abridgment of their metamorphosis, and it is not at all improbable that other species of Gonodactylus may have an Erichthoidina stage.

The *Challenger* collection contains a bottle of very minute and young larvæ in the Erichthoidina stage, and one of these is shown in Fig. 3 of Pl. xii of my report. Comparison between this and the newly hatched Erichthus of our species, Pl. xiv, Fig. 3, will show many points of resemblance, and future research may possibly prove that it is the larva of Gonodactylus, although the statement that all Gonodactyli hatch as Erichthoidinæ is an error.

CHAPTER IV.

THE METAMORPHOSIS OF ALPHEUS.

By W. K. Brook and F. H. Herrick.

(With Pls. I, II, IV, XVI to XXIV.)

Section I.—The Metamorphosis of Alpheus minor from Beaufort, North Carolina.

This small species is found in abundance at Beaufort, North Carolina, and in the Bahama Islands, and it is no doubt widely distributed along our southern coast. At Beaufort it is found in shallow vertical burrows in the sandy mud which forms the bottom of most of the land-locked sounds between tide marks. It is also met occasionally in shells, and under loose stones and oyster shells.

During its development, between the time when it hatches from the egg and the time when it acquires the adult form, it passes through a long metamorphosis, divided into many stages. Its life history has been traced by one of the authors at Beaufort, and by the other at Nassau, and the individuals from both these localities pass through exactly the same series of changes. As we also find that other species, such as *Alpheus normani*, pass through the same metamorphosis, the life history of *Alpheus minor* may be regarded at the primitive or ancestral life history of the genus, which originally characterized all the species; although it is now retained in its perfect form by only a few, and has undergone secondary or recent modifications in the others.

THE FIRST AND SECOND LARVAL STAGES.

The stage in which the larva hatches from the egg is of very short duration, as it molts and passes into the second stage within a few hours after hatching. No drawings of it were made before the change, but this is very slight, and the description of the second stage holds true in all essentials of the first stage, except that the tips of the exopodites of the three pairs of maxillipeds, and the plumose hairs on the antennules and antennæ are not fully extended until after the change.

The second larval stage is shown in Pl. XVI, Fig. 2, and in Pl. XVII, Fig. 2, and various organs of the larva during the first stage are shown in Pl. XVI, Figs. 4, 6, 7, and 8, and Pl. XVIII, Fig. 4. In Pl. XVI, Fig. 4, is the antenna of the first larval stage, Fig. 6, the first maxilla, Fig. 7, the second maxilla, Fig. 8, the mandible, and Fig. 4 of Pl. XVIII, the first maxilliped. As shown in Pl. XVII, Fig. 2, and in Pl. XVI, Fig. 2, the locomotor organs of the larva during the first and second stage are the plumose exopodites of the antennæ and of the three pairs of maxillipeds. There are no functional appendages posterior to the maxillipeds, and the large eyes are freely movable and entirely uncovered.

The larva has all its appendages fully developed and functional as far back as the third pair of maxillipeds. Following these are three bud-like rudiments of the first, second, and fifth pairs of thoracic limbs, and posterior to these a long tapering abdomen, divided into six segments, there being at this time no joint between the telson and the sixth abdominal segment. During the first

stage there are no traces of any abdominal appendages, but in the second stage, the outlines of the sixth pair are faintly visible under the cuticle of the telson, as shown in Pl. XVI, Fig. 2. The stomach is almost completely free from yolk, and the surface of the body is marked by red and yellow pigment spots, which are very constant in position and number, and are well shown in the figures.

As shown in Pl. XVI, Fig. 2, the antennule consists of a stout shaft composed of a long basal portion with no trace of an ear and a much shorter distal joint, which carries externally a much shorter and smaller joint with four sensory hairs, and internally a long slender plumose hair, which is not fully extended until after the first moult. At this stage this hair is almost sessile upon the shaft, although its base is destined to give rise to the long flabellum of the antennule of the adult.

The antenna has a large exopodite, which is fringed with plumose hairs, and is an efficient organ of locomotion. During the first larval stage this exopodite, which is destined to become the flat scale of the adult antenna, is cylindrical and distinctly annulated, as shown in Pl. XVI, Fig. 4. At this stage it is divided into a basal portion and five movable joints, about equal in total length to the basal portion. After the first molt the annulations become less distinct, although the "scale" is still cylindrical, as shown in Pl. XVI, Fig. 2. The basal joint of the antenna is about equal in length to the "scale," undivided, and it carries upon the inner edge of its distal extremity a small, short, movable joint, with a single, long, plumose hair, which is "telescoped" before the first moult, but fully extended afterwards. This short joint is the rudimentary antennal flagellum, which in the adult is equal in length to the entire body of the animal.

The mandible is shown in Fig. 8. It is deeply cleft into two branches, the outer one with two rows of large, strongly marked dentations, and the inner one with a rudimentary palpus, two rows of hairs, and a finely serrated cutting edge. The first maxilla is very small, but it does not appear to be rudimentary. It is shown in Pl. XVI, Fig. 6. No exopodite could be made out. There is a small endopodite, with one long, plumose hair, and two basal joints, one with two sharp cutting hairs and the other with one. The second maxilla is shown in Pl. XVI, Fig. 7. The two basal joints are feebly indicated, and each carries three slender, simple hairs. The endopodite carries two terminal hairs, and the flat exopodite is fringed by seven. I could not determine whether these hairs are plumose or not. The three pairs of maxillipeds are functional and they present features which are characteristic of the genus Alpheus (see Pl. XVI, Fig. 2). Each has a large, flattened, polygonal, basal joint, which carries upon its inner edge a few short, sharp teeth, and upon its outer edge a long, flat exopodite, with plumose swimming hairs, and an endopodite which presents several peculiar features.

The endopodite of the first maxilliped is very short and two-jointed, that of the second is somewhat longer and five-jointed, while that of the third is very greatly elongated, without traces of joints, and ending in a long, simple hair which, as shown in Pl. XVIII, Fig. 4, is telescoped before the first moult, but immediately afterwards becomes lengthened, as shown in Pl. XVI, Fig. 2, until it reaches forward beyond the tips of the antennules and antennæ. Following the maxillipeds are three pairs of buds to represent the first, second, and fifth pairs of thoracic limbs. The first bud consists of a single branch, which is shown by its subsequent history to be the exopodite. The second has two branches, a short exopodite, and an extremely short endopodite, while the third consists of a somewhat longer, but still rudimentary, shaft, which represents the endopodite of the fifth thoracic limb, and has no trace of an exopodite.

The hind body is divided by joints into five abdominal somites, behind which is a long undivided region to represent the sixth abdominal somite and the telson. Before the first moult none of the abdominal appendages are present, but after this molt the sixth pair are faintly indicated under the integument of the telson, as shown in Pl. XVI, Fig. 2. The telson itself is broad, subtriangular, with its posterior border nearly straight and transverse. It carries eight pairs of stout plumose hairs, of which three pairs are much longer than any of the others and nearly equal. This set of three spines is placed at the angle of the posterior edge on a lobe or elongation, which, while it is so slightly marked as to scarcely interrupt the triangular outline, is still very distinct and easily recognizable. Of the remaining five spines on each side of the middle line, one is on the external border, and the other four on the posterior edge between the group of three and the middle line. The internal one is very small and might easily be overlooked.

THE THIRD LARVAL STAGE.

(Pl. XVI, Fig. 1.)

After molting the second time the larva assumes the form shown in Pl. XVI, Fig. 1. It is also shown, much less enlarged, in side view in Pl. XVII, Fig. 1. The first and fifth thoracic limbs are now functional, the second is represented by a bud, all the abdominal somites are distinct, and the sixth abdominal appendage has made its appearance. The first five abdominal appendages are still unrepresented, and the endopodite of the sixth is rudimentary, although its exopodite is fully developed and functional.

Those appendages which were present in stage two have undergone little change. The external branch of the antennule has, in place of the four sense-hairs of the earlier stage, only two, which are much longer than before. The long terminal hair of the inner branch has lost the marginal hairs of the earlier stage and is now simple, while two plumose hairs have made their appearance on the lower surface of the distal joint of the shaft. The scale of the antenna is still cylindrical, but the annulations which marked it during the earlier stage have disappeared. The flagellum still consists of only one short joint, and the long terminal hair which it carried at the earlier stage has disappeared. The mandibles, maxillæ, and maxillipeds are about as they were before, but the endopodite of the third maxilliped has almost completely lost the long terminal hair of stage two, and has also become relatively shorter, and is now divided into four joints.

The first thoracic leg, which was rudimentary in stage two, has now acquired a flat basal joint and a plumose exopodite, like those of the preceding appendages, but the endopodite is represented only by a rudimentary knob or bud upon the anterior edge of the basal joint. The second thoracic limb is, as it was at the earlier stage, a two-lobed bud. No buds have as yet appeared between it and the base of the fifth thoracic appendage, which is now fully developed and forms the most conspicuous peculiarity of this stage in the development of Alpheus. It has no exopodite, its basal joint is not enlarged nor flattened, and its long, slender, cylindrical shaft, made up at this stage of four joints, is prolonged at its tip into a long, slender, tapering, simple hair, the end of which reaches beyond the tips of the antennæ when the appendage is in the position shown in the figure Pl. XVI, Fig. 1. The appendage seems to have little power of motion and it seldom deviates much from the position shown in the drawing, being usually carried closely pressed against the ventral surface of the body between the bases of the other appendages, with its tip directed forward. All six abdominal somites are distinct and movable, but the first five have as yet no traces of appendages. The first four somites are short and equal, the fifth is nearly as long as the first four together, and the sixth is very narrow and almost twice as long as the fifth. The endopodite of the sixth abdominal appendage is present and of considerable size, but it is not as yet functional, although the exopodite, which is not very much larger, is fringed by six long, plumose, swimming hairs and is used in locomotion. The two spines which are carried upon the lateral margins of the telson at an earlier stage have disappeared, and there is less difference than before in the relative sizes of the others, but the general form is the same.

FOURTH LARVAL STAGE.

The subsequent history of *Alpheus minor* was traced by one of the authors at Beaufort and by the other at Nassau, but as the stages which follow were found to be almost exactly like the corresponding stage of other species which had already been drawn, it did not seem to be advisable to make new figures, and in the remainder of the description the illustrations which are referred to actually represent the larvæ of other species. After its third molt the larva of *Alpheus minor* passes into its fourth stage, when it becomes almost exactly like the fourth larval stage of *Alpheus heterochelis*, shown in Pl. XVIII, Fig. 3. There is little change at the anterior end of the body, except that the carapace now begins to extend over the eyes, and the ears have made their appearance in the basal joints of the antennules. The mandible has lost its outer branch, and the basal joint of the second maxilla, Pl. XVI, Fig. 5, carries on its inner edge three hairy lobes. There are now five pairs of swimming appendages in place of the three of stages one and two, and the four of stage three. These five are the exopodites of the first, second, and third maxillipeds

and those of the first and second thoracic legs. The endopodites of the maxillipeds are as before. The endopodite of the first thoracic leg, which was represented in stage three by a rudimentary bud, now appears to be entirely wanting. The second thoracic limb, which in stage three was represented by a bilobed bud, now consists of a basal joint, with a large, functional, plumose exopodite and a rudimentary, bud-like endopodite. Between this appendage and the base of the fully developed fifth thoracic limb there is a row of buds to represent the third and fourth thoracic limbs, which became developed after the next molt. The fifth is about as it was in the preceding stage, and it carries no trace of an exopodite. The abdomen is about as before, except that the endopodite of the sixth abdominal appendage, the only one yet represented, is now fully developed and fringed like the exopodite by long, plumose, swimming hairs. The telson has become elongated and narrow, and the spines upon its posterior end are much smaller than before.

THE FIFTH LARVAL STAGE.

None of the figures of the larvæ of other species exactly represent the larva of *Alpheus minor* after the next molt. The eyes are now partially covered by the carapace, and the swimming organs are the seven pairs of fully developed exopodites belonging to the three pairs of maxillipeds and the first four pairs of thoracic legs. At this stage these four pairs of appendages reacquire their endopodites, and the anterior end of the body is similar to that of the larva shown in Pl. XXI, Fig. 1, from which, however, it differs greatly as regards the telson and the sixth abdominal appendage. The first five abdominal appendages are now represented by buds like those shown in Pl. XXI, Fig. 1, and in Pl. XIX, Figs. 1 and 2, but the terminal portion of the abdomen is nearly like that of Fig. 3 in Pl. XX. The telson is greatly elongated, narrow, and its terminal spines are very small.

THE OLDER LARVAL STAGES OF ALPHEUS MINOR.

During the successive molts the abdominal appendages become fully developed, the eyes become completely covered by the anterior edge of the carapace, the antennæ become elongated, the antennule develops a scale, the swimming exopodites of the maxillipeds and thoracic legs disappear, these appendages assume their adult form, and acquire gills, and the animal gradually becomes like the one shown in Pl. XX, Fig. 2, which is a young Alpheus of another species.

THE METAMORPHOSIS OF ALPHEUS HETEROCHELIS FROM THE BAHAMA ISLANDS.

In the Bahama Islands this species passes through a series of stages which, except for a few minor differences of detail, are exactly like those in the life history which has just been described.

This fact is remarkable when it is known that the life history of the same species is very different at Beaufort, North Carolina, and that Packard has described still another life history for specimens of the same species which he studied at Key West.

FIRST LARVAL STAGE.

The Bahama specimens hatch from the egg in the stage shown in side view in Fig. 1 of Pl. XVIII. As this larva agrees in all details of its structure with the first stage of *Alpheus minor* shown in Pl. XVII, Fig. 2, already described, no further description is necessary.

THE SECOND LARVAL STAGE.

Like *Alpheus minus* the Bahama specimens of *Alpheus heterochelis* molt within a few hours after hatching, but they undergo no essential change, and Pl. XVI, Fig. 2, exhibits all the essential characteristics, although this figure was drawn from a specimen of *Alpheus minor*.

The most noteworthy specific difference is in the relative length of the marginal spines of the telson. In the first and second larval stages of both species there are eight pairs of spines, one pair on the outer edge and seven on the posterior edge, as shown for *Alpheus minor* in Pl. XVI, Fig. 2, and for *Alpheus heterochelis* in Pl. XVI, Fig. 3. In both species the pair next the median line are rudimentary and the next pair very small, but the three which arise from the rounded angle of the

telson are much more nearly equal to the others in *Alpheus heterochelis* than in *Alpheus minor*. If, as seems probable, the triangular telson of the *macrouran zoëa* is a secondary modification of the deeply furcated telson of a more ancient protozoea, then the first larval stages of *Alpheus minor* are in this respect more primitive or protozoean than those of *Alpheus heterochelis*.

THE THIRD LARVAL STAGE.

This is shown from below in Pl. XVIII, Fig. 2, and a comparison with Fig. 1 of Pl. XVI will show its very close resemblance to *Alpheus minus* at the same stage. The only essential difference between them relates to the rudimentary thoracic limbs. In both species the first thoracic limb has a functional swimming exopodite and a rudimentary endopodite, and in both the fifth thoracic limb has a greatly elongated jointed cylindrical endopodite and no exopodite, but between these limbs *Alpheus heterochelis* has buds to represent the other three pairs of thoracic limbs, while *Alpheus minor* has buds for only one pair, and the other buds do not appear until after the next molt.

THE FOURTH LARVAL STAGE OF ALPHEUS HETEROCHELIS.

This is shown from below in Pl. XVIII, Fig. 3, and there are no noteworthy differences between it and *Alpheus minor*.

THE LATER STAGES OF THE BAHAMA ALPHEUS HETEROCHELIS.

The transformation of the larva into the adult Alpheus occupies a number of molts, and the general character of the changes will be understood by the study of Pl. XIX and XX, although these plates were drawn from Beaufort specimens of the species.

THE METAMORPHOSIS OF ALPHEUS HETEROCHELIS FROM BEAUFORT, NORTH CAROLINA.

As shown in Pl. XX, Fig. 1, this, before it hatches from the egg, reaches a stage of development which somewhat resembles stages two and three of the Bahama specimens. There are many important differences however, and the stage in which it hatches is not directly comparable with any stage in the life of the Bahama form, nor in that of *Aipheus minor*. Just before hatching it has, like the Bahama form immediately after hatching, three pairs of fully developed swimming maxillipeds, but it also has buds to represent all five pairs of thoracic legs. The antennary scale and flagellum are much more advanced than they are at a much later stage in the Bahama form, and the abdomen is much more distinctly segmented. The larva, immediately after hatching, is shown in side view in Pl. XIX, Fig. 2, and in ventral view in Fig. 1. The antennule and antenna are shown on a larger scale in Figs. 3 and 4, and the mandible and first and second maxillæ in Figs. 5, 6, and 7 of the same plate. The animal now has all the appendages which are present in the adult, but all behind the maxillipeds are rudimentary, although they all become functional after the first molt, as shown in Pl. XX, Fig. 3.

The antennule, Pl. XIX, Fig. 3, has a long cylindrical shaft made up of three joints fringed with plumose hairs and terminating in an exopodite with sensory hairs and an endopodite or flagellum, which is short and rudimentary but much longer than it is in the younger stages of the Bahama specimens. The antenna, Fig. 4, presents even greater differences. The flagellum is about as long as the scale, and two jointed, while the scale itself is flat, although its tip still presents traces of a primitive segmented condition. It is, however, of little use in swimming, and in fact the larva has at this stage only very feeble locomotive power. The eyes are stalked and movable and almost completely uncovered. The mandible is simple and without a palpus, as shown in Fig. 5. The first maxilla, Fig. 6, is very small, but apparently it is not rudimentary as its two lobes carry cutting hairs. The second maxilla, Fig. 7, is a broad flat plate, very much more developed than that of the newly hatched Bahama specimen shown in Pl. XVI, Fig. 5.

The three pairs of maxillipeds (Pl. XIX, Fig. 1) are almost exactly like those of the newly hatched Bahama larva (Pl. XVIII, Fig. 1) or those of the *Alpheus minor* at the same stage (Pl. XVI, Fig. 2), but the thoracic appendages (Pl. XIX, Fig. 1) are entirely different, and the ventral surface of the body is covered by a mass of limbs closely crowded, all pretty well developed, but all as yet

functionless. Careful examination shows that there are five pairs (the five pairs of thoracic limbs), and that all but the last pair are biramous. In all, the exopodites are longer than the endopodites, which decrease in length from in front backwards, while the endopodites increase in length. The later history of these limbs shows that the exopodites never become functional, as they do in the Bahama form.

All six abdominal somites are distinct, although the line separating the sixth from the telson is faintly marked. The first five pairs of abdominal feet are represented by five biramous buds projecting beyond the outline of the body, while the sixth pair are only faintly outlined under the cuticle of the telson, which itself presents a most important difference from that of the young Bahama larva, as it is not triangular, but spatulate; and of the eight pairs of setæ the three pairs which in *Alpheus minor* lie on the lobe at the angle of the telson are not on a distinct lobe, nor do they differ in size from the adjacent setæ.

This larva molts a few hours after hatching, and at once undergoes the most profound changes, and assumes the form shown in Pl. XX, Fig. 3. It is no longer a larva, but a young Alpheus. The eyes are almost covered by the carapace, the ear is well developed, and all the appendages are present and functional and essentially like those of the adult. The antennule has two flagella, each with several joints. The flagellum of the antenna is more than twice as long as the scale and is composed of twenty-two joints, while the scale has its final form.

The first maxilla (Fig. 5) has a large club-shaped lobe, fringed with short hairs, and a rudimentary endopodite, while the second maxilla (Fig. 6) is a broad flat plate with cutting lobes and a short, rod-like endopodite. The three pairs of maxillipeds (Figs. 7, 8, and 9) have assumed the characteristic Macrouran form and are no longer concerned in locomotion, while the thoracic limbs have elongated into the five pairs of ambulatory appendages of the adult, although they still retain their rudimentary exopodites. The abdomen is now like that of the adult, and the telson (Fig. 4) is long and narrow. An older specimen is shown in Fig. 2 and a still older one in Pl. XVII, Fig. 3.

Comparing the history of the Bahama form with that of the North Carolina form, the most conspicuous peculiarity, and that which first attracts attention, is the great abbreviation of the latter. The Beaufort specimens hatch in a much more advanced condition than the Bahama specimens, and, while the latter pass through many larval stages, the former quickly assume the adult form. This is not all, nor is it even the most fundamental difference between them. The development of the Beaufort specimens is not simply accelerated; it is profoundly modified, so that no exact parallel can be drawn between any larval stage of the one and a stage of the other. The statement that the Beaufort specimens pass, before leaving the egg, through stages which are exhibited during the free life of the Bahama specimens would do violence to the facts; for the difference between them is very much more fundamental than this statement would imply. For example, the Bahama form has at first three, then four, then five, and then seven schizopod feet with functional swimming exopodites, while the Beaufort form never has more than three. As regards the thoracic region and the first five abdominal appendages the Beaufort larva, at the time of hatching (Pl. XIX, Fig. 1), is more advanced than the fourth larval stage of the Bahama form (Pl. XVIII, Fig. 3), while the sixth pair of abdominal appendages are like those of the Bahama form at the time of hatching (Pl. XVI, Fig. 3). In the Bahama form the first and fifth thoracic limbs are the oldest, and the others appear in succession from in front backwards; all five pairs make their appearance together in the Beaufort form. In the Bahama form the sixth pair of abdominal feet appear before and in the Beaufort form after the others. Many minor differences of the same general character show that we have to do with profound modification of the life history rather than with simple acceleration.

The Development of Alpheus heterochelis from Key West.

According to Packard's account the specimens of *Alpheus heterochelis* which occur at Key West differ from those which occur at Beaufort in about the same way that the latter differ from those from the Bahamas, as the metamorphosis appears to be entirely absent in the Key West specimens. Packard states that, while still inside the egg, they had all the appendages of the adult in essentially the adult form. There were five pairs of thoracic legs and the first pair had large

chelæ, and the eyes were nearly sessile. In this case also there seems to be modification as well as acceleration, as Packard says that there were only five pairs of abdominal feet and that these were well developed. It may seem to some that the fact that these three forms present such great and constant differences in development is a reason for regarding them as three distinct species, but, whether we hold that they belong to one, two, or three species, they will still furnish proof of the existence of profound modifications in the life histories of adults which have remained almost exactly alike.

Careful and minute comparison between adult specimens from Beaufort and Nassau showed the closest agreement in nearly all particulars (v. Chap. v, Pt. First, Section II), and it has therefore seemed best for us to regard them as belonging to a single species; the more so since our discovery that different individuals of another species found at Nassau (*Alpheus saulcyi*) differ from one another during their larval stages in somewhat the same way that the Beaufort specimens of heterochelis differ from the Bahama specimens.

Alpheus minor and *Alpheus heterochelis* are very distinct species. The adults have diverged from one another so far that one could not possibly be mistaken for the other; yet the life history of the Bahama heterochelis is so exactly like that of *Alpheus minor*, both at Beaufort and in the Bahamas, that the same figures of the early stages will serve for both; for the larval stages of heterochelis have undergone local modifications, while the adults have remained almost absolutely unchanged, except as regards the reproductive elements and their product.

Section V.—Larval development of Alpheus saulcyi.

An egg of *Alpheus saulcyi* just ready to hatch is shown in Pl. XXI, Fig. 5. The large claws are plainly visible through the transparent shell. The antennæ are folded back alongside the body, while the abdominal and closely packed thoracic appendages are directed forward. The telson overlaps the head.

First larva (length, $= \frac{15}{100}$ inch).—Fig. 1 shows the larva as it is just hatched. It belongs to the variety found in the brown sponges. The various parts may be seen more highly magnified in Pl. XXI, Figs. 4, 6, 7, 9, and Pl. XXII, Figs. 1–8, 12. In both varieties the animal hatched as a schizopod, loosely infolded in a larval skin, but not invariably, as I have noticed that in one or two cases, where females of the longicarpus with very few, perhaps half a dozen eggs, produced young, the metamorphosis was completely lost, the larvæ being in a stage corresponding to that usually attained after the second molt and represented in Pl. XXI, Fig. 8 This is referred to again at the end of the section.

To return to the first larva (Pl. XXI, Fig. 1); this is fifteen one-hundredths of an inch long. It is semi-transparent and colorless, except for spots of characteristic red and yellow pigment sprinkled freely on the abdomen, the telson, and appendages. Rudimentary gills are present and a remnant of unabsorbed green yolk is conspicuous in the stomach. The carapace covers the bases of all the thoracic appendages but the last pair. It is produced forward into a short simple spine, the rostrum, which extends between the eyes. There is a rudiment, on either side, of the ocular spines (Pl. XXII, Fig. 6), which soon grow forward and give to the front the characteristic trident shape. The eyes project forward, only the extreme base of the stalk being covered by the carapace. A median eye or ocellus is present just below and between the bases of the lateral eye stalks.

Both pairs of antennæ are biramous and jointed. The antennules (Fig. 8) consist of a stout peduncle, a short endopodite, and a shorter bud or outer branch, which bears several bunches of sensory filaments. The peduncle is composed of three segments, as in the adult; the basal joint being four times the length of either of the other two, and bearing on its outer side a rudimentary aural scale. The upper margin of each joint carries one or more plumose hairs. The antennæ (Pl. XXII, Fig. 7) are formed on the adult plan. There is an inner antennal stalk consisting of two joints, bearing a rudimentary flagellum, and an outer scale or exopodite. The distal margin of the exopodite is garnished with plumose hairs and carries a short outer spur.

The mandibles (Fig. 12, drawn from a larva after the first moult) are deeply cleft, as in the adult. The outer branch is dentated at its distal end and carries a palpus. The first maxillæ (Fig. 6,

shown with more detail in Fig. 3, Pl. XXII) have adult characters. They are biramous. The endopodite is stout and toothed at its apex. The more slender outer division bears a short spine near the distal end. In the second maxillæ (Fig. 6, Pl. XXI) the scaphognathite or respiratory plate is most prominent. This is now composed of an anterior portion, bordered with from six to twelve long plumose hairs and a posterior, rudimentary, and hairless lobe. The inner division (endopodite) has the adult form, while the innermost lobes of the adult appendage (Pl. XXIV. Fig. 9) are unrepresented.

The maxillipeds are all biramous appendages, and their exopodites are the principal swimming organs. The endopodite of the first pair is short and stout and divided at its tip. That of the third pair is three-jointed and equal in length to the exopodite. In the first pair of thoracic legs (Pl. XXI, Figs. 4 and 7) the inequality of the chelæ is very marked, and, as we have already seen, it is so for some time before hatching. Individuals differ somewhat in this respect. The articulations of the carpus and meros are distinct. The exopodites of this and of the three succeeding pairs of thoracic limbs are tipped with rudimentary invaginated hairs. The second pair of pereiopods (Pl. XXII, Fig. 1) are chelate, but the articulations of the carpus are not distinct. The third pair of pereiopods (Fig. 2) end in bidentated dactyles and have short exopodites. The fifth pair are without swimming organs.

All the abdominal appendages are present and functional, excepting the sixth pair. They have only very short hairs until after the first moult. The first pair (Pl. XXII, Fig. 5) consist of a larger outer and smaller inner blade. This endopodite remains rudimentary in the adult male, but nearly equals the exopodite in length in the female, as will be seen by reference to Pl. XXIV, Figs. 4 and 5. This convenient sexual mark probably appears early, but can not be relied upon at this stage. The second (Pl. XXII, Fig. 4) and three succeeding pairs of pleopods have a stout base, an outer blade like that of the first pair, and a shorter endopodite which bears on its inner margin a lobule or palp. The sixth pair, or uropods (Pl. XXI, Fig. 9), are not yet free. The inner and smaller divisions point forward, meeting on the middle line. The telson, which terminates the body, covering the outer uropodal limbs, is a rounded, spatulate plate, with a median notch. Its free posterior edge is fringed with seven pairs of plumose spines, the first or median pair being rudimentary, and the next four succeeding pairs long and nearly equal.

Second larva (length, $\frac{16}{100}$ inch).—The first moult takes place either immediately or very soon after hatching. The animal as it now appears is shown in Pl. XXI, Fig. 2. The principal external changes thus produced are the following: (1) The rostrum and ocular arches extend farther over the eyes. (2) Both divisions of the antennules are considerably extended. The flagella of the antennæ are from three to four times their former size and are articulated into twenty to thirty rings, the scale still not passing the peduncle. (3) The thoracic appendages have more of the adult characteristics. The articulations of the carpus of the second pair are distinct. The exopodites of the first four pairs are functional, and the last pair has grown forward. (4) The pleopods presently acquire swimming hairs; the telson plate is free and the uropods are functional for the first time. (5) The last thoracic segment is still uncovered and the eyes are incompletely hooded.

Third larva (length, about $\frac{1}{6}$ inch).—The third larva as it appears after the second moult, which takes place in twenty-five to thirty hours after hatching, is represented in Pl. XXI, Fig. 8. It has now the general adult character, and can not be called a larva in the strict sense. At even this early age the pugnacious instinct is strong, and although only about one-sixth of an inch long, it snaps audibly the fingers of its large "hand," which is carried extended forward. It also swims on the bottom of the jar in all respects like the adult. Only a few globules of yolk remain in the stomach. The gills are now quite prominent. They are evidently functional to some degree, and were so, possibly, at an earlier date. The yellow and red pigment cells have nearly all disappeared or are temporarily withdrawn from view.

A most prominent change at the second moult is the extension forward of the rostrum and the ocular spines, which form a hood over each eye. The antennal peduncle surpasses the scale, and its flagellum nearly equals the carapace in length. As in the adult, the large chelæ are very prominent. The exopodites of the thoracic appendages have dwindled to rudiments. The view of the head of a four-days old Alpheus is shown in Fig. 3, Pl. XXI.

The fourth form (after third moult).—When six or seven days old the third moult is passed, but only slight changes are introduced. The small chela and the inner and outer antennæ of this phase are given in Figs. 9, 10, 16, Pl. XXII. The inner branch of the antennules is still relatively short; the basal or aural spine extends to nearly the end of the first joint. The bristle-bordered plate of the antennæ has now developed a considerable spine near its outer extremity, a rudiment of which appears in the first larva (Fig. 7). This represents the squamal spine, to which the plate is ordinarily attached, in the adult. The spine is here developed from the plate. The latter may disappear, as we shall see further on, to be finally regenerated from the base of the spine. The small chela has the adult form.

The fifth form (after fourth moult).—These animals moulted the fourth time ten days after hatching. Very little change was apparent, except in size, and beyond this point we did not follow them.

METAMORPHOSIS OF ALPHEUS SAULCYI FURTHER ABBREVIATED.

As was stated above, the metamorphosis of *Alpheus saulcyi* may be still further accelerated so as to practically disappear altogether. This fact is illustrated by a young Alpheus hatched in a glass dish April 25 (Fig. 17, Pl. XXII). The prawn (var. *longicarpus*) was taken from a brown sponge. The eggs, half a dozen in number, were slow in developing. The small chela is shown in Fig. 15.

This phase corresponds with that usually attained after the second moult (shown in Fig. 8, Pl. XXI), with which it corresponds in size and color. All the thoracic and abdominal appendages have nearly the adult form, the exopodites of the former being rudimentary, as in Fig. 8. The large chela is most prominent, being nearly as large again as the smaller one. The eyes are partly hooded, but not so much as the four-day old prawn represented by Fig. 3. The Alpheus had to be held in a compressorium in order to be drawn, so that the parts are slightly distorted by pressure. At the time of hatching most of the hairs on the appendages generally are in a rudimentary condition.

V.

ALPHEUS: A STUDY IN THE DEVELOPMENT OF CRUSTACEA.

By Francis H. Herrick.

CONTENTS.

Introduction.
Methods.
Part First:
I. The habits and color variations of Alpheus.
II. Variations in *Alpheus heterochelis*.
III. The abbreviated development of Alpheus and its relation to the environment.
IV. The adult.
V. Variations from the specific type.
VI. Measurements.
VII. The causes and significance of variation in *Alpheus saulcyi*.
Part Second:
I. Structure of the first larva of *Alpheus saulcyi*.
II. The origin of ovarian eggs in Alpheus, Homarus, and Palinurus.
III. Segmentation in *Alpheus minus*.
IV. The development of Alpheus.
First stage: Segmentation to formation of blastoderm.
Second stage: Migration of cells from blastoderm to the interior. The invagination-stage.
Third stage: Optic disks and ventral plate.
Fourth stage: Thickening of optic disks. Rudiments of appendages.
Fifth stage: Rudiments of three pairs of appendages. Optic disks closely united by transverse cord. Degenerative changes.
Sixth stage: The egg-nauplius.
Seventh stage: Seven pairs of appendages formed.
Part Second—Continued.
IV. The development of Alpheus—Continued.
Eighth stage: Nine pairs of appendages present.
Ninth stage: Eye-pigment formed.
Tenth stage: Ganglia of ventral nerve-cord distinct and completely separated from the skin.
Eleventh stage: Embryo about to hatch (*Alpheus heterochelis*).
Twelfth stage: First larva (*Alpheus saulcyi*).
Thirteenth stage: Young Alpheus, four to ten days old.
V. Notes on the Segmentation of Crustacea.
VI. Cell Degeneration.
VII. The Origin and History of Wandering Cells in Alpheus.
VIII. The Development of the Nervous System.
IX. The Eyes.
The median eye of the larva and adult.
General anatomy of the eye-stalk.
Structure of the ommatidium.
Arrangement of the ommatidia.
The development of the compound eye.
(1) Origin of the optic disk.
(2) Development of the retina and the optic ganglion.
The eye under the influence of light and darkness.
X. Summary of Part Second.
XI. References.
Explanation of figures (accompanying each plate).
[With thirty-eight plates.]

INTRODUCTION.

The observations offered in this memoir were undertaken at Beaufort, North Carolina, in June, 1885, at the Marine Zoological Station of the Johns Hopkins University. But little was accomplished, however, until the next and following seasons, 1886–'87, when I enjoyed the advantages of this laboratory in the Bahama Islands.

A part of this memoir was accepted as a thesis for the degree of Ph. D. by the Board of University Studies of the Johns Hopkins University in May, 1888.

I take this opportunity of thanking Professor Brooks for his invaluable counsel, aid, and encouragement from the beginning to the end of the work.

At Nassau, New Providence, during a sojourn of four months (March to July, 1887), I had the rare opportunity of a making a comparative study of a large number of Crustacea. At least thirteen species of Alpheus were discovered on the coral reefs and shores of New Providence, and in all these the eggs have been obtained, and in nearly all the larvæ or first zoëas have been hatched in aquaria. Many of these forms are new or but little known, and when the means of publication is found it is hoped that their comparative and systematic zoölogy can be fully illustrated.

The majority of the decapod Crustacea have a long and complicated metamorphosis. That in a few forms the early stages are jumped, so that the young hatch in practically the adult condition, is a remarkable fact, and the discovery of a probable cause for this phenomenon in Alpheus is one of the most interesting results of that part of our work which deals with the metamorphosis of the genus.

The development of Alpheus has never, I believe, been previously studied, excepting the metamorphosis of the two Beaufort species, so that there is no work of others to refer to, which bears directly upon our subject. But the literature of the Arthropods is very great, commensurate indeed with the size of the group. During the progess of this work a number of important papers have appeared which are referred to either in the text or in notes. While much is known of the Arthropods as a whole and of that large division of them included under the Crustacea, it is probably true that a great deal of this knowledge is of a very fragmentary and unsatisfactory nature. There is great need for detailed and full accounts of the development and organogeny of many forms in order that the relations of the various members of the Arthropod type may be clearly established.

The present work may be regarded as a contribution toward supplying the need just mentioned, but how imperfectly it is unnecessary to say.

The plan of making observations upon other Crustacea for comparison with the more detailed studies of Alpheus has been as yet only partially carried out. The early stages of *Stenopus hispidus*, *Homarus Americanus*, and *Pontonia domestica* have, however, been followed, and less completely those of *Hippa talpoides* and *Palæmonetes vulgaris*.

Spence Bate (3) states that the shortened development of Alpheus was first described in his memoir, with drawings, communicated to the Royal Society in 1876, from a specimen procured in the Mauritius. He named his specimen *Homaralpheus*, "from the impression that species producing a Megalopa could not be placed in same genus as those producing a Zoëa." He says: "The original of my drawing is 2^{mm} in length and was procured from a specimen 14^{mm} long, resembling the figure that I have given of *Alpheus minus*, Say. An inspection of this drawing (3, Pl. CXXII, Fig. 1) leaves some doubt as to whether there was not an error in referring this form to the genus. The general shape is unlike that of Alpheus, the abdomen being three times as long as the carapace, and there appear to be only three pairs of thoracic appendages behind the chelipeds.

Packard (46) in 1881 was the first to describe a shortened metamorphosis for *Alpheus heterochelis*. In some brief notes published in the American Naturalist of that year, he states that both this and the small green Alpheus (*A. minus*) occur in abundance at Key West, Florida, in the excurrent openings of large sponges. This fact is interesting, and probably significant also, as will be later shown. Packard describes the first larva of this Florida form as much further advanced toward the adult state than is the first zoëa of the Beaufort species, according to the observations of Brooks. In fact it more nearly agrees with the first larva of a Bahaman Alpheus soon to be described, in which the metamorphosis is nearly lost. The Nassau form of *Alpheus heterochelis* has, as I have recently ascertained, a *complete metamorphosis*. The bearings of these facts will be discussed further on.

The larval development of the Beaufort Alphei was studied by Brooks (7) and a short abstract of his results was published in 1882. This is all, I believe, that has been previously done on the embryology of these Crustacea. Several abstracts of the present work appeared in 1887–'88 (20–22).

METHODS OF WORK.

Several species of prawns, such as Stenopus and Pontonia, repeatedly laid eggs while kept in aquaria, and doubtless I should have succeeded equally well with Alpheus, if sufficient pains had been taken. As it was, only two or three individuals gratified me in this respect, but in each case the ova failed to develop. The animals were therefore taken from the sea with eggs in the earliest phases of development, and were kept under observation in an aquarium for the length of time required. The ova were then carefully removed from the pleopods, and were hardened at intervals of thirty minutes or one hour or a longer time, according to the phase or age of the embryo. By obtaining a number of series in this way the whole life history within the egg could be followed, and by

this means I was able to observe the peculiar movements of the wandering cells and the formation of germ-layers, which are often very difficult to interpret, when we rely upon material taken by chance.

Experience with the use of Perenyi's fluid in preparing the eggs led me to discard this reagent altogether, and to substitute for it Kleinenberg's picro-sulphuric acid, made up either with water or 30 per cent alcohol. The alcoholic solution works equally well and economizes time. The Perenyi is too violent and uneven in its action. While it serves fairly well in some cases, it generally swells out the membranes or shell by the rapid endosmosis, and distorts some part of the egg or embryo in consequence. The egg is frequently deformed and the shell ruptured. The ova should be transferred directly from the killing fluid to 70 per cent alcohol, and they will then generally retain their normal shape, and can thence be removed to alcohol of a higher grade for permanent keeping. If, however, they are carried from the Kleinenberg fluid to a weaker alcohol (30 per cent), distortion is sure to follow, the capsule bursting and the egg sometimes exploding.

Preparations of the entire embryo as well as sections were made, but very little was attempted with the living egg. For surface preparations the hardened ova were first punctured to allow the fluid to penetrate the shell more easily and they were then stained entire, in Kleinenberg's hæmotoxylon. They were afterwards shelled, when this was possible; saturated with paraffin by the *turpentine-paraffin* method, and were then mounted. While the paraffin was congealing they were carefully placed in position with a hand lens. This last important and often troublesome process was rendered easy by the differential property of the stain, which affects only the embryonic cells, leaving the ylok, which in preserved eggs is of a light straw color, unaltered. The embryonic tissues are thus made to appear nearly black on a light background. The embryo was then cut away from the rest of the egg by the microtome razor; attached to the slide by collodion and mounted in balsam; or the egg was cut in two and both halves were similarly treated. All drawings which represent surface views excepting Fig. 10 were made from objects thus prepared.

In general, Kleinenberg's hæmotoxylon proved to be the best staining fluid, and it is especially useful in this case, where the massive yolk contains numerous elements, the relations of which it is important to determine. The carmines are less serviceable, since the food yolk is also affected by them. Soda carmines (Beccari's formula) proves to be incapable of removing pigment from the eyes, although it is specially recommended for this purpose. This may be easily effected by soaking the entire tissues in very weak solutions of nitric acid for a considerable length of time. Gaule's quadruple stain of hæmotoxylon, eosin, saffranin, and nigrosin was also tried with excellent results, but this method is very laborious, and since our inquiries do not extend in most cases, to cell structure it is unneccessary.*

Perenyi's fluid is sometimes available for swelling the chorion and thus aiding in its removal, although the embryo is liable to injury. It is also helpful in studying the egg with low powers. The food yolk, which is often dark green, is affected less actively by this reagent than the embryonic tissue. The latter is turned to a waxy whiteness and is thus clearly defined for a short time, but the yolk is soon decolorized unless the eggs are transferred to water, becoming pink, and finally light yellow after preservation in alcohol.

Part First.

I.—The habits and color variation of Alpheus.

Some facts of general interest have been gathered from a study of the Alpheus in its natural environment on the coral shores and reefs of the Bahamas, and in giving these we will limit ourselves mainly to the three species which have contributed the material for the history of the embryo, viz: *Alpheus minus* Say, from Beaufort, N. C., *A. heterochelis* Say, from Beaufort, N. C., and Nassau, New Providence, and *A. saulcyi*, from Nassau, New Providence. The genus Alpheus comprises numerous species spread over a large part of the globe, many of which are closely connected by intermediate forms. From North America upwards of twenty species of Alpheus have been described; five are known to inhabit the eastern coast of the United States, three from Florida, and two others (*A. minus* and *A. heterochelis*), which range from Panama to as

* In studying the development of the lobster, which has also a large egg, I have found it necessary to adopt new methods, especially in the treatment of the eggs for surface preparations. In most cases the egg-membranes are best removed by the aid of hot water.

far north as Virginia. From Florida and Cuba nine species are recorded. I have found twelve species of this prolific genus, or about one-half the number described for the whole American continent, inhabiting the beautiful little reef of growing coral called Dix Point to the eastward of Nassau Harbor and along the margins of the little bay which was just in front of our laboratory. Another species (*A. websteri* Kingsley), first reported from Florida, was also discovered on Green Key reef, a few miles from Nassau.

From collections which I made at Abaco and Andros Islands, I am led to believe that the different species are quite generally distributed in the Bahamas, and as these islands have probably been largely populated from the South, we may expect the same forms to occur at Cuba and at other West Indian Islands. This genus, however widely distributed, is essentially tropical and abounds in all coral seas. Of the great family of the Crustacea which make their home on the submerged reefs of growing coral, Alpheus is perhaps the most prominent and thoroughly characteristic. They pop out of almost every rock which is brought up from the bottom, and every loose head or block of growing coral, with its clusters of algæ, sponge, and sea fans, which you pull from the reef, resounds with the click of their little hammers.

Some of these animals lead a semi-parasitic life in sponges, or seclude themselves in the porous limestone which forms the solid floor of the beach, and others, again, live under loose shells and stones in the white coral sand. Some are highly and beautifully colored, and with few exceptions the pigment is characteristic of the species for any locality. In all cases the claws of the first pair of walking legs are enormously enlarged and serve as formidable weapons of defense so remarkable in this genus, and in most there is the greatest disparity in the size of these claws, one, either the right or left, being the larger. One species, the habits of which are peculiar, carries the larger of these claws so folded under the body as to be completely concealed. It can, however, quickly withdraw this weapon and make a rapid thrust when an enemy comes near.* By the scissor-like blades of the large claws a sharp metallic report is produced. This is true of nearly all the species, and so abundant are many in these islands that a constant fusilade is kept up along some of the shores at low tide. This snapping propensity is shared by both sexes whether in or out of the water, and it is undoubtedly correlated with their pugnacious habits. If two males or females of the same or different species are placed in the same aquarium, they will dismember each other in a very short time, and one is usually literally torn to pieces.

The sounds emitted by *Alpheus heterochelis* are the loudest I have heard from any member of this genus. We frequently kept this species in glass dishes in our room for several days at a time, and sharp reports like the explosion of a small torpedo or pop gun were heard at intervals through the day and night. It sometimes swims with its large claw so widely opened as to suggest dislocation. This weapon then reminds one of a cocked pistol, and the report apparently follows in the same way that the click follows the impact of the hammer on the lock. I have given this mattter no closer attention, but find that Mr. Wood-Mason, who is quoted in a notice on "Stridulating Crustacea"† in "Nature," (65) has offered another explanation. According to this observer the sound always accompanies a sudden opening of the claws to their fullest extent, and may be caused either by impact of the dactyle upon the joint to which it is articulated or "by forcible withdrawal of the huge stopper-like tooth of the dactylopodite from its pit in the immovable arm in the claw." It seems most probable to me that the sound is caused by impact, and most likely by the rapid closure of the finger into its socket.‡

---

*This species is entirely new. The large concealed claw suggests a poison apparatus. The "fingers" are exceedingly slender and sharp at the points. Although kept for over a week in an aquarium it emitted no sounds.

†According to Wood-Mason sound-producing organs in Crustacea were first brought to notice by Hilgendorf, in V. der Decker's "Reisen in Ost-Africa (Crustaceen)," and were afterwards observed by himself in his dredging expedition to the Audaman Islands. The stridulating organs—scrapers and rasps—may be either on the carapace and appendages or on the appendages alone.

‡Both Kent and Wood-Mason speak of the sounds emitted by the Alphei as if produced by the extension or opening of the claw. As pointed out above, it is just the other way, the sound following upon the impact of dactyle and propodus, when the tooth of the dactyle is not pulled out of its socket but driven into it. None of the conditions of piston movement are present. The walls and floor of the pit are relatively soft, while the tips of the claw are dense and stony. The "click" can be artificially produced when the claws are clamped with rubber, whether the "stopper" is present or not.

In *Alpheus heterochelis* the dactyle of the large pincers is a curved blade which shuts down into a groove on the occludent margin of the "thumb," and closes over the latter like a pair of shears. The huge stopper-like tooth is borne on the inner and proximal edge of the dactylopodite and fits neatly into a corresponding pit in the "thumb," in line with the groove just mentioned. The object of this plug is evidently to steady the movable dactyle and to prevent lateral strain and the dislocation which might result, and thus to give it a strong grip on any object which it has seized. In alcoholic specimens in which the relations of the parts are well preserved the stopper works freely in and out the well, and not like a "tightly packed piston from a cylinder closed at one end."

(The claw is widely opened, before the sound is produced, but the sound is not produced while the claw is open, but at the instant when it is violently and suddenly closed. It is due to the impact of the "thumb" and "finger," and I have frequently seen specimens of *A. heterochelis*, when prepared for combat, facing each other for several seconds with claws distended to the utmost. In these cases the "snap" does not come until the claw is closed. In fighting the claw is not used as a clasper, but as a saber. The sharp external edge is a weapon of such efficiency that I have seen individuals killed and almost cut in two by a single blow.—W. K. B.)

A large brown sponge, *Hircinia arcuta*, which is not to be mistaken, grows on the shallow reefs and off the shores of all the Bahama Islands which I visited. It is found from just below low tide mark out to one-half a fathom or more of water, where its great size and sooty brown color distinguish it at once on the white bottom. These "loggerheads" are round and much flattened (the smaller ones more vase-shaped), and of a coriaceous texture; they sometimes measure 1½ feet in diameter. There is commonly one, sometimes two, large exhalent chimneys into which small fish, young spring lobsters, and other Crustacea, often beat a hasty retreat. It is easily broken open since it has no consistent skeleton. If a sponge colony of this kind is pulled and torn apart, one is certain to find it swarming and crackling with a small species of Alpheus, which quarter themselves in the intricately winding pores of the sponge. The sounds emitted from every fragment of these mutilated sponges remind one forcibly of "those made when sparks are taken by the nuckles from the prime conductor of a small electrical machine," as Wood-Mason remarks. Hundreds of individuals may be collected from a single large specimen.

These animals have an average length of about 12^{mm}. They are nearly colorless, excepting the large chelæ, which are tipped with brown, reddish orange, or bright blue. The females are so swollen with their eggs or burdened with the weight of those attached to the abdomen that they can crawl only with great difficulty, if taken from the water. The eggs are few in number and of unusually large size, their diameter varying from one-twenty-second inch to one-twenty-fifth inch, and their number from six to twenty. These are most commonly yellow, but may be either bright green, olive, greenish white, brown, brownish yellow, or dull white. The ova and ovarian eggs have always the same tint in the same individual. Although translucent and apparently colorless, upon close inspection the body is seen to be sprinkled with cells of reddish and yellow pigment.

Another quite different sponge grows on all the reefs in from one to two fathoms or more of water. There are several varieties of this, which may be told by their olive green color, yellow flesh, and clumpy, irregular shape, as well as by the putrescent mucous which some of them pour out when broken open. In about nine out of ten of these sponges one will find a single pair of Alpheus (rarely more than this), which resemble those living in the brown sponge, but differ from them in several important points. We are concerned at the present with the color variations only. They are distinguished by their large size (averaging about 23^{mm} in length) and uniform color. The females exceed the males greatly in bulk, owing to the large size and number of their eggs. In both sexes the large claws are bright red (v. Pl. IV, and for details section IV).

The female is practically inert during the breeding season, and at such times is well protected in her sponge or against any green surface by the bright green ovaries which fill the whole upper part of the body and by the mass of similarly colored eggs attached to the abdomen below. Only two pairs, or four individuals, out of a hundred or more which were examined showed any variation from these colors. In these the eggs were yellow, and the pigment on the claws was more orange than red. The table which follows shows the variations between two large females taken, respectively, from the brown and green sponges, and between the size, number, and color of the eggs.

Habitat of Alpheus.	Length of ♀.	Number of eggs.	Diameter.	Color.	Color of adult.
	Inches.		*Inches.*		
Brown sponge...	$\frac{1}{2}$	19	$\frac{1}{22}$	Yellow (variable)....	Large chelæ, red (blue or brown in others.)
Green sponge....	$1\frac{5}{16}$	347	$\frac{1}{25}$	Usually green; in this case yellow.	Large chelæ, orange-red.

These two forms, although apparently distinct, are seen, however, by closer study to belong to the same species; but besides the more superficial variations just mentioned, there are others of a more remarkable character, the morphological significance of which is considered in sections IV and V.

Of this species, *Alpheus saulcyi*, Guérin, it is necessary, for descriptive purposes, to distinguish two varieties, viz:

Alpheus saulcyi, variety *longicarpus* (from brown sponges),
Alpheus saulcyi, variety *brevicarpus* (from green sponges).

These two varieties shade completely into each other by numerous intermediate forms. The *longicarpus* varies greatly in size and in the color of the body and eggs (besides the other more profound variations mentioned in section V), while the *brevicarpus* type from the green sponges is more uniform in size and stable in color and other characters. The former variety is well protected from outside enemies while in the tortuous mazes of its sponge, as its great numbers would show, if any evidence under this head were needed. The enemies which invade them successfully seem to be parasites.*

Possibly the variety inhabiting the green sponge does require color-protection, especially since the females are very inert during the breeding season. They are, indeed, admirably protected when exposed on the green surface of sponges, algæ, etc. The bright color on the tips of the large claws, which only are protruded from the places of concealment, recall the similarly colored heads of boring annelids, which abound on the reef, but this fact may have no significance.

It seems quite probable that if we have in this Alpheus a case of protective coloring, it is due very largely to individual adaptibility. This view implies great individual plasticity, which does not appear in any of the species of Alpheus known to me *within a restricted area.*

The colors of certain Crustacea, and also the colors of their eggs, are known to vary greatly with the surroundings. In the Alpheus, parasitic in the brown sponges, these colors vary considerably where the surrounding conditions are the same. However, the color of the ovarian eggs is always the same as that of those already laid, and, although these animals were kept for several days at a time in differently colored dishes, I never observed any very marked change in the color of the ovary, but these experiments were not continued long enough or carefully enough to be conclusive. The eggs of *Alpheus heterochelis* are almost invariably of a dull olive color, while, as in the case of the parasite of the green sponge, about one in a hundred has bright yellow eggs. In the first case at least this may possibly be an instance of reversion to one of the original colors from which the green was selected. In most species of Alpheus the color of the eggs is fixed and uniform for any locality, and, as already suggested, may have a protective significance; but in a few other cases, where this is not true, the color is not only variable in different individuals, but probably also in the same individual.

Alpheus heterochelis from Beaufort, N. C., is uniformly of a dark olive-green color, with some red and blue on the appendages. It lives in the beds of oyster shells, which are more or less

---

* A parasitic Isopod, probably a *Bopyrus*, is found on both the varieties, but is most common with the dweller in the brown sponge. It appears as a tumid bunch, firmly rooted in the branchial cavity or to the under side of the abdomen. In this connection I will mention another curious parasite which was found infesting the eggs of a single female taken from a brown sponge at Abaco. This is a large, spherical, unicellular organism in the encysted state. The egg, with the embryo, is packed full of them. (V. Fig. 199 and section IV, Part Second.)

In looking over a collection of unpublished drawings of Crustacea, made by the associates of Louis Agassiz and deposited in the library of the Museum of Comparative Zoölogy of Harvard College, I find a sketch (by H. J. Clark, December 23, 1857) of a *Bopyrus* taken from the branchial cavity of *Alpheus heterochelis*.

exposed at low tide. *Alpheus minus* has a similar environment and is similarly colored. *Alpheus heterochelis* from Nassau, New Providence, on the other hand, lives under loose stones, amid the white coral sands of the beach, and is noticeably transparent, looking as if the color had been bleached out of it. The body is sprinkled with dots of brown pigment. The claws and legs are pale greenish. Young and old are invariably colored alike.

In a collection of adult Alpheus of either sex of the same or of several species, where there is a difference in size of the large claws, it is noticed that either the right or the left, indifferently, may be the greater. As we will see, this differentiation of the chelæ begins in one instance before the animal is hatched. Is this right and left handed condition to be explained by inheritance from the parents? In about forty larvæ of a small brood of *Alpheus saulcyi*, all invariably had the *left* claw enlarged, and in a smaller number (all that were preserved), from another female of the same species, the left chela was also in each case the larger. This would indicate that the young of the same mother have always the same claw, either right or left, the greater, and that this phenomenon is one of direct heredity from the parents. But to prove this it is only necessary to trace right and left handed broods to parents which are themselves right and left handed, respectively. This, unfortunately, I have not done, as my attention was not called to the subject while at the seashore.*

The breeding season of Alpheus begins at Beaufort, N. C., about April 1. It covered the period of our stay at Nassau (March to July), and probably began earlier and lasted considerably later.† There the temperature is high and remarkably constant, the annual range being about 15° (temperature of air 70° F. in March, 80° in June), and in consequence the early phases of development are rapidly passed. Not one prawn in a hundred was found with eggs in an earlier stage than that of yolk segmentation.

II.—VARIATIONS IN ALPHEUS HETEROCHELIS.

A renewed comparison of *Alpheus heterochelis* with the Nassau form lends support to the conclusion already reached that we here have to do with two varieties of the same species. There are certain differences, which systematic zoölogists might regard as of specific value, but they are no greater than we have proved to exist among individuals of the same species living in the same sponge. (v. Section V.)

The Nassau specimens average smaller, but the chief difference lies in the shape of the small chela. The propodus of this appendage in the Nassau form is relatively shorter and thicker in both sexes. Both fingers are nearly cylindrical, and covered with hairs, which are distributed either singly or in tufts. In the Beaufort *heterochelis* there is a striking variation in the small chela which appears to have escaped detection. Judging from the small collection at my command it is a sexual variation. In the females the small chela is like that of the Nassau form, but is usually longer and slenderer. The dactyle is about one-half the length of the propodus. In the males the dactyle is relatively much shorter, and has a median longitudinal carina which is continued into the apex of the claw. In transverse section the dactyle is trihedral, with two concave sides, corresponding to the deep groove on either side of the keel. These grooves are fringed with a row of stout plumose setæ. Similar rows of setæ occur on the sides of the opposing "thumb."

Perhaps the most interesting variation which I have observed in the Beaufort *heterochelis* has reference to the size of the egg. The eggs in this locality have an average diameter of about one

---

* Mr. J. J. Northrop, of Columbia College, while at Nassau in the winter and spring of 1890, kindly offered to collect for me some specimens of *Alpheus saulcyi* with young. On February 10 he collected six females, five from green sponges, one of which had a brood of sixteen young, and one small female with three larvæ from the "loggerhead" sponge. In the first instance the left chela was the largest in the *mother* and in *each of the sixteen young*. In the latter, two had the right claw enlarged and one the left. The inference is suggested that when the claw of the same side is invariably the greater in all the young, this character is doubly inherited from both father and mother, but the data are insufficient to settle this point.

† Professor H. V. Wilson found this species breeding around Green Turtle Key from July until December. Mr. Northrop found newly hatched young early in February. It therefore breeds the year through, which is probably true of many of the Crustacea.

twenty-fourth inch, but two females were found which carried a few bunches of very small eggs, normally glued to the anterior swimmerets. These eggs measured only one fifty-third to one sixty-fifth inch in diameter, that is, the contents of the smaller was about one-twelfth that of the larger egg.

This occasional production of very small eggs exhibits a tendency, which is still present in the species of this locality to-day, to revert to its old metamorphosis long since laid aside.

III.—THE ABBREVIATED DEVELOPMENT OF ALPHEUS AND ITS RELATION TO THE ENVIRONMENT.

Related species, as a rule, resemble each other more in their early stages of development than in their adult state. This is not, however, invariably true, since all animals, whether young or adult, must adapt themselves to their environment or be destroyed. It is probable that animals in all stages of growth are equally plastic and tend to vary with the varying conditions of life.

The early life in large classes of the animal kingdom, as fishes, birds, and mammals, is spent either in the protecting membranes of the egg or within the body of the parent, and is thus but slightly affected by *external conditions*, and suffers little change in consequence. In other groups, on the contrary, and in the Crustacea in particular, the case is very different. Here the young are usually hatched in a very immature condition, and lead a life of their own at the surface of the ocean, wholly independent of their parents. They have accordingly adapted themselves to this mode of life, and the variations thus entailed have led to the production of the zoëa, a locomotor larva, fundamentally different from the adult. We may regard the zoëa as a secondary, adaptive form, directly descended from an ancestral protozoëan type. After passing a longer or shorter period (usually of several weeks) at the surface of the sea, the adult state is gradually reached through a complicated series of changes, and the animal adapts itself to new conditions on the sea bottom or on the shore.

Now, if the habits of the adult and larva should tend to converge, if the adults should adapt themselves to an entirely new environment, which it is necessary for the young to become fitted for at once as soon as hatched, we would expect that the zoëal stages, formally assumed to bridge over a gap which no longer exists, would be dropped or shifted to the egg. This seems to have actually taken place, and is illustrated in a remarkable manner in the genus Alpheus.

Most of the species, which are very numerous, inhabit the shores, in common with many related forms, and, as already stated, they abound on coral reefs. They all, as a rule, hatch as zoëa-like and have a complicated metamorphosis. Two species have been discovered, however, which have adopted a parasitic life, and in each the larval period is accelerated. In one, which is semiparasitic, the metamorphosis is partially abbreviated; in the other, which is completely parasitic, the metamorphosis is completely lost. Still more interesting and significant is the fact that *one of the species in one locality is nonparasitic and has a complicated metamorphosis, while the same species from another locality is parasitic and has the metamorphosis abridged.*

We will now consider more particularly the history of these two forms, in order to make a clearer comparison. The species are—

(1) *Alpheus heterochelis*, from Nassau, New Providence.
(1) *Alpheus heterochelis*, from Beaufort, North Caralina.
(1) *Alpheus heterochelis*, from Key West, Florida.
(2) *Alpheus saulcyi*, from Nassau, New Providence.

ALPHEUS HETEROCHELIS FROM THE BAHAMAS.

This species, found at Nassau, exemplifies the development common to the genus, as seen, for instance, in *A. normani* (Kingsley), which is closely associated with it, *A. minus* Say, and in many other Bahaman forms. It is one of the common species at Dix Point, and may be found in abundance on the shore of the little bay, in pools left by the ebb tide, under shells or loose fragments of coral.

First larva (length = $\frac{1}{9}$ inch).—The three pairs of maxillipeds, each with long exopodites ending in feathered hairs, are the principal locomotor organs. Two pairs of rudimentary thoracic legs are present. All the abdominal segments, but none of their appendages, are formed.

The antennules consist of a stout jointed stalk, the terminal segment of which bears four sensory filaments. A long plumose spine springs from the extremity of the second joint on the inner side.

The antennæ are biramous, the two branches arising apparently out of a common basal segment. The outer division is a scale-like plate. It bears on its extreme inner border a row of plumose hairs, eight to ten in number. The endopodite is slender and shorter than the scale. It terminates in a short spine or denticle, from near the base of which springs a long plumose hair. The eyes are large and uncovered. The mandible is simple.

The telson is a broad triangular plate, the terminal side of which is garnished with the characteristic zoëal spines, the number, relative size, and position of which vary slightly in the different species. There are in this case eight pairs of these spines. The first or median pair is rudimentary; the second is not half the length of the third. The lateral angles of the plate are each prolonged into a short lobe, bearing three spines. There is no marked median notch, but there is a slight median depression. The rudiments of the sixth pair of abdominal appendages are plainly seen.

Second larva.—With the first molt the endopodites of the maxillipeds lengthen. Three pairs of rudimentary pereiopods are now present, the last of which are the longest. Of the pleopods only the sixth pair are represented, whether free or not was not observed.

ALPHEUS HETEROCHELIS FROM BEAUFORT.

The peculiar metamorphosis of the Beaufort *Heterochelis* was described in 1884 by Brooks, who also showed that in this respect it departs widely from the associated *Alpheus minus*.

The form in question is hatched as a larva with preparations for the schizopod stage. It has the usual swimming organs, but all the thoracic legs are present in the condition of rudimentary buds. The abdominal segments are formed, and the buds of the first five pairs of feet belonging to them. The eyes are not completely covered by the carapace. At the first molt the rudiments of the sixth pair of abdominal feet are added, and the larva undergoes profound changes. All the appendages are now functional and the eyes are nearly hooded. With later molts the adult characters become more pronounced, but the marked difference of the great claws appears only after several months.

ALPHEUS HETEROCHELIS FROM FLORIDA.

The short description, given by Packard in 1881, of the first larval stage of this species from Key West, where it inhabits sponges, has already been alluded to. From this we infer that the development is considerably more abridged than in the Beaufort case. This is also indicated by his figure of one of the abdominal appendages. He says: The eyes are nearly sessile, the yolk nearly absorbed, although the embryo (in the egg) was near the time of hatching. The antennæ are "well developed." All the thoracic legs are present, their joints distinct, "the first pair about twice as thick as the others, the claws rather large, but not so disproportionately so as in the adult form, but as much so as in the larva in the second stage of the lobster. Abdomen broad and flat, spatulate at the end, much as in the adult. There were five pairs of abdominal feet or swimmerets, each with endopodite and exopodite, like those of the second larval stage of the lobster."

ALPHEUS SAULCYI FROM THE BAHAMAS.

In this form, the metamorphosis of which is fully described in another paper, we have either an abridged development in which the general adult characters, very marked in the first larva, are all acquired in twenty four hours after hatching, or a case where the short metamorphosis is done away with entirely, so that the animal leaves the egg in the full adult form.

Comparing the histories just given with the one before us, we find that the first larva of *Alpheus saulcyi* is about equivalent to the third larva of the *Heterochelis* from Beaufort, and rather more advanced than the first larva of this species from Florida.

The eggs of the Alphei, with the development unabridged, are invariably small and quite numerous. In the two species, however, with shortened metamorphosis, the ova are fewer and many times larger. Moreover, as would be expected, the degree of abbreviation is correlated with the

size and number of the eggs. These and the other facts which we have been considering are given in tabular view below:

Species.	Habits.	Metamorphosis.	Number of eggs.	Diameter of egg.	Length of female.
				Inch.	*Inches.*
Alpheus minus (from Beaufort).	Non-parasitic	Complete	*500	$\frac{1}{54}$	$\frac{1}{2}$–1
A. heterochelis (from Nassau) ...	....do	....do	300–500	$\frac{1}{44}$–$\frac{1}{50}$	$\frac{3}{4}$–1$\frac{1}{4}$
A. heterochelis (from Beaufort) .	....do	Abridged	150–300	$\frac{1}{24}$–$\frac{1}{27}$	1–1$\frac{3}{4}$
A. heterochelis (from Florida) ..	Semi-parasitic.....	....do	.....	.....	.....
A. saulcyi (var. brevircarpus) ...	Completely parasitic.	Nearly lost	100–350	$\frac{1}{28}$	$\frac{1}{2}$–1$\frac{2}{3}$
A. saulcyi (var. longicarpus)....	....do	Completely absent (in some cases).	5–20	$\frac{1}{23}$–$\frac{1}{25}$	$\frac{1}{4}$–$\frac{5}{8}$

* Number not accurately determined.

The eggs of Alpheus are usually spherical when freshly laid, but they change their shape, becoming more elongate in course of development and increase somewhat in size.* The eggs of *A. saulcyi* are usually oblong. They vary from one twenty-eighth to one twenty-third of an inch, taking the mean of the long and short diameters. The extreme limits of the number of eggs vary somewhat from the numbers given above, which are the average limits.

In the genus Alpheus we thus have several stages in the abbreviation of the metamorphosis between the macrouran zoëa stage and the adult form. What is the cause of this gradual suppression of the zoëa like form? The conclusion seems to be unavoidable that in the Bahaman species this shortened life of the larva is directly related to the conditions of life. As the adults of the species in question became more and more dependent upon a semiparasitic† mode of life, it would be clearly beneficial to reduce the larval period, in order that the young might be hatched fitted to live in an environment similar to that of the adults. If the zoëa brood were swept out to sea by the tides, and were to spend several weeks in the larval condition at the surface of the ocean, the chances for large numbers to find particular sponges along the shores, when the adult state was reached, would be greatly lessened. It is likely that the larvæ of this Alpheus are never carried far from the shores, but while they undoubtedly leave the sponge in which they are born, they probably establish themselves very soon in a new one. (The young remain a short time after hatching, attached to the swimmerets of the mother.)

This supposition is strengthened by what we know of the peculiar history of *Alpheus heterochelis.* The Nassau heterochelis probably never changed its adult habits or adopted a parasitic mode of life; consequently it has retained undisturbed its complex larval development. The Floridian form has become a parasite, and its metamorphosis is accelerated as the result. From this the Beaufort Alpheus with its less abridged development has doubtless been derived (the species extending northward from the Gulf of Mexico), and it is within the possible, at least, to suppose that in this form the metamorphosis, once lost by parasitism, is now being reëstablished.

No fewer than three species of macroura, together with the Alpheus above described, occur in the large brown sponges (*Hircinia arcuta*) of the Bahama islands. These (one of which is also an Alpheus) live in the larger oscula, are less regular in their occurrence, and evidently have not adopted a stationary parasitic life. In none of them is the metamorphosis of the larva abbreviated. *Alpheus minus* is also reported as occurring in the large exhalent openings of sponges at Key West, but in this case we do not know, first, whether this is a fixed or only a transient habit, and secondly, we know nothing of its metamorphosis under these conditions.

Thus while in Alpheus the abbreviated metamorphosis may be explained as an adaptation to a parasitic mode of life, the question is probably often complicated by conditions which are not easy to determine. There is a general tendency among the higher forms of certain groups, as in the Cephalopods among the Mollusca, to reach the adult conditions rapidly by omitting some of the early embryonic stages.

---

* An egg of *A. saulcyi* var. *longicarpus*, just ready to hatch (Pl. XXI, Fig. 5), measures $\frac{4}{100}$ by $\frac{6}{100}$ inch.

† The Alphei which inhabit sponges are commensals rather than parasites in the strict sense. They derive protection from the sponge colony, and receive the benefit of the circulating currents of water which are set up within it.

An abridged larval development has been attributed to the following macroura: The lobster *Homarus americanus;* the crayfishes; *Hippolyte polaris; Palæmonetes varians; Palæmon potiuna; Palæmon adspersus* and *Eriphia spinifrons* (as first observed by Rathke, according to Packard); *Bythocaris leucopsis* (observed by G. O. Sars, according to S. I. Smith); *Alpheus heterochelis*, and *A. saulcyi.* To this list we must probably add the names of many deep-sea decapoda, *Munidopsis, Glyphocrangon, Elasmonotus inermis, Sabinea princeps, Acanthephyra gracilis*, and *Pasiphaë princeps*, as inferred by S. I. Smith, on account of the extraordinarily large size of their eggs. An egg of remarkable dimensions is that of "the little shrimp (*Parapasiphaë sulcatifrons,*) which carries only fifteen to twenty eggs, each of which is more than 4 millimeters in diameter, and approximately equal to a hundredth of the bulk of the animal producing it—a case in which the egg is relatively nearly as large as in many birds!" "Although the great size of the eggs," says Prof. Smith, "is highly characteristic of many deep-water species, it is by no means characteristic of all, and the size of the eggs has no definite relation to the bathymetrical habitat, and is often very different in closely allied species, even where both are inhabitants of deep water (59)."

The larval life of both terrestrial and fresh-water Crustacea is generally short as compared with that of marine forms, and the case of the crayfish may find an explanation in the well-known law that fresh-water life tends to shorten the development, as is shown in a remarkable manner in the fresh-water variety of *Palæmonetes varians*, described by Boas (4). Why, on the other hand, it is beneficial for the lobster to abbreviate its larval development is not plain, since its young at the present time hatch apparently under the same conditions as other pelagic larvæ, and, like them, swim at the surface of the ocean. S. I. Smith (58) and Ryder (55) have given accounts of the larval history of the lobster. (Since this paper was written I have undertaken a revision of this subject, and the results will be given in a fully illustrated report to the United States Commissioner of Fish and Fisheries.) While this animal hatches in a precocious state its life at the surface is by no means short, since, according to Ryder, it ordinarily requires seven weeks to pass through six molts. The first larva hatches in a schizopod stage, but there are no abdominal legs and the antennæ are somewhat rudimentary. The first ecdysis, according to Ryder, does not occur until from three to six days after hatching.* It is in the second stage that the second to fifth pairs of abdominal appendages make their appearance.

The third stage is preceded by a molt ten to fifteen days after hatching, and now the appendages of the last abdominal segment are formed. After the fourth molt (fifth stage) the young lobster, now 14^{mm} long, quite closely resembles the adult. It swims more on the bottom. The flagella of the antennæ are equal to the cephalo-thorax in length. The exopodites of the thoracic legs are reduced to bare rudiments. The chelipeds show adult characters. The first pair of swimmerets are developed in the seventh stage, at the end of which there is a decided difference between the great claws.

It will be seen that the fifth stage in Ryder's account, attained at the end of the third week, nearly corresponds with the third larva of *Alpheus saulcyi* (Fig. 8, Pl. XXI) as it appears twenty-four hours after hatching, but the latter has the more decided adult characters. The young Alpheus is further advanced than the lobster at the time of hatching and reaches maturity in a remarkably shorter period.

Boas calls attention to the fact that while the young of the salt and fresh water forms of *Palæmonetes varians* are very different, the adults of these two varieties resemble each other very closely. Much more remarkable is the case of *Alpheus heterochelis*, even if we regard the Nassau form as a distinct species, and that of *Alpheus saulcyi*, where we have the same species living in the same sponge, hatching now as a larva and now as a form possessed of all the external adult characters.

Both the long and short metamorphosis has been attributed to the West Indian shore crab *Gegarcinus.* This highly colored crab (*Gegarcinus ruricola*) is very abundant at Nassau, and from its exceptionally large egg we may safely infer that the development has here been shortened. Fritz Müller (42) has found abbreviated development in the South American crabs, *Trichodactylus* and *Æglea* ("mountain crab").

---

*A delicate moulted skin, which is easily overlooked, either comes off with the egg membranes at the time of hatching or is shed shortly after, as my own observations have clearly shown.

The habits of the hermit crabs, though secondarily acquired in comparatively recent times, have had no tendency to shorten the larval period. This is also true of the *Pinnotheres*. Similarly the commensalism of such forms as *Pontonia domestica*, which lives in the mantle cavity of several species of Pinna, has in no way affected its development.

IV.—THE ADULT.

The Alpheus whose development has just been traced was provisionally named *Alpheus præcox* (22), in allusion to its greatly accelerated metamorphosis. It has since been found to agree in most particulars with the description and figure of *Alpheus saulcyi* given by Guérin in Ramon de la Sagra's History of Cuba (18). In Guérin's drawings the long spine (squamal spine) of the antennæ is represented as continuous throughout its length with the scale, and the carpus of the second pair of thoracic legs as divided into three segments. The segmentation of the carpus of this appendage is one of the most constant of specific characters. If these figures are accurately drawn, the two forms in question are certainly not specifically identical; but though not at first able to satisfy myself on this point, or to decide from the short and imperfect description, it seemed best after further study to adopt Guérin's name.

The systematic zoölogy of the genus Alpheus is in a very unsatisfactory state, and in the absence of adequate and well executed drawings, and too often with only vague or general descriptions, the attempt to identify the less known species is apt to be attended with most doubtful success.

It is now necessary to complete the account of the metamorphosis of this Alpheus by giving a description of the adult form. The *Alpheus saulcyi* resident in certain green sponges found on the Bahama reefs is regarded as the typical form of this species.

DIAGNOSIS.

Carapace ends anteriorly in three spines. The median spine or rostrum inclined, especially in the female; arises from the edges of the carapace, like the lateral or orbital spines; barely surpasses the latter in length; without keel. Body and appendages generally smooth; large chela slightly twisted, smooth, no transverse constrictions; small chela subcylindrical, short; dactyle nearly straight, slender, one-half as long as propodus; carpus of this appendage short. Aural spine of inner antenna variable in length; rarely surpasses the middle of the second segment. Basal segment of outer antenna is produced into an outer, inferior spine, and an upper rudimentary spur; articulated with it is a squamal spine, on which is developed a conspicuous scale. Carpus of second pair of thoracic legs superficially segmented into five parts.

SPECIAL DESCRIPTION.

Length: Smallest found in green sponges, 9.5^{mm}, ♂; largest, 42^{mm}, ♀; average length, 25 to 30^{mm}. Females exceed the males a little in length, and greatly surpass the latter in size when swollen with their eggs.

Color: The color of this form is shown in Pl. IV. Large claw vermillion above, fading out towards proximal half, and nearly colorless below. On upper face of claw a transverse colorless band is often seen. Small chela often tinged with red, also the terminal segment of the third pair of maxillipeds. Body, pale, translucent, with scattered cells of reddish or yellow pigment, subject to quantitative variation, and visible to the naked eye on close inspection or by aid of a lens.

A young male which was kept for several days in an aquarium molted and lost completely the bright color of its claws. Sexes are colored alike, excepting the eggs and ovaries of the female, which are bright green.

In one or two instances a pair of these Crustacea were found which exhibited a variation from these tints. In these cases the male and female were of light-reddish orange and the claws deep orange red, darkest on the "fingers"; eggs and ovaries of female golden yellow. Length of ♀, 33^{mm}. Number of eggs attached to abdomen, 347. The male in this case also, after a moult, was apparently colorless, contrary to the rule that upon molting the colors are enhanced.

The carapace is smooth, translucent, and, like the abdomen, takes on more or less the hue of the yellow or green ovaries. It ends anteriorly in a trident, formed by the median rostrum and

ocular spines. The rostrum is short, subacute, broader at base than long, feebly convex above, without crest. The orbital spines are separated from the rostrum by a shallow superficial groove, and the marginal notch on each side has a regular V-shaped outline. Length of spines and width of notch are slightly variable.

The lateral compression of carapax is not marked. Frontal angle (angle made by middle line above and below rostrum, greater in ♀ than in ♂. In some females with the carapace bulged out by the ovaries the angle is as great as 45°. In males without conspicuous "forehead" frontal angle, 10°.

The telson ends bluntly. It is two-thirds as broad as long, and twice as broad at base as at apex. There is a single pair of short spines at the posterior extremity on either side the middle line, and two (or more) separate spines upon either side further forward. There is a wide and shallow median depression.

The compound eyes are conspicuous, owing to their dark pigment and the transparency of the carapace, and in the largest adults they show no traces of degeneracy. There is a permanent *ocellus* (Pl. XXII, Fig. 18), which occupies the same position and has the same characters as at birth. It consists of a pigmented body embedded in a short median papilla, situated below the compound eyes and between the bases of the antennules.

The antennules (Fig. 4, Pl. XXIII) consist of a three-jointed stem or protopodite, an exopodite, and endopodite. The first segment of the stem is largest and bears an external spine (aural spine), which protects the auditory sac. The latter is large and conspicuous in this genus. It usually contains some pigment cells and grains of sand. Second segment about half as long as first; third, four-fifths as long as second. Endopodite one and one-half times the length of stalk, slender. Exopodite compound, a slender flagellum branching from near the end of the stouter proximal portion. On the under side of the latter the sensory filaments (olfactory setæ) are borne, distributed in seven to ten bunches of two to three in a bunch.

The antennæ (Fig. 8, Pl. XXIII) are composed of three parts—a basal portion (protopodite), which carries a squamous spine (exopodite), and on its inner and lower side a long three-jointed stem, which bears a flagellum (endopodite).

The protopodite consists of a proximal segment (coxopodite) and a larger distal one (basipodite). A prominent papilliform process is seen on the inner side of the coxopodite at its point of junction with the basipodite. Upon it the duct of the green gland probably opens to the exterior. The basipodite is continued into a prominent spine below and into one or more rudimentary spurs above. To it is articulated a long, stout, scale-bearing spine. The scale plate, usually shorter than the spine and attached to it for less than half its length, is fringed on its inner free edge with plumose setæ. The antennal stem or peduncle consists of two short proximal segments and a long distal one, which carries the multarticulate flagellum. The latter is often hairy, and is two to three times the length of the peduncle. The relative lengths of the different parts for an average specimen is shown in Fig. 8, Pl. XXIII, and in Pl. IV.

The mandibles (Fig. 3, Pl. XXIII) are strongly bifurcate, as is characteristic of the genus. The larger division is finely tuberculated, while the masticatory surface of the slenderer branch is raised into sharp teeth. This bears a jointed palp (endopodite) on the inner side. The mandibular palpus is short; its terminal segment large and hairy.

The first maxilla (Pl. XXIV, Fig. 7) consists of three divisions—a smaller branch (endopodite), a larger branch (basipodite), divided at the apex and terminated by several long spines, and a larger spatula-shaped fork, the maxillary surface of which is beset with spines (coxopodite). (v. Description of figure.)

The second maxilla (Pl. XXIV, Fig. 9) is composed of three portions. (1) The long respiratory plate; the "bailer" or scaphognathite, fringed with a row of setæ. (2) An outer and lobulated division (coxopodite and basipodite), the inner edge of which are closely set with bristles, and (3) a median rudimentary endopodite.

The first pair of maxillipeds (Fig. 7, Pl. XXIII) are made up of a long, strap-shaped exopodite, with jointed setæ at the extremity and a small setigerous plate at its base; a small, two-jointed endopodite, protopodite, and epipodite. The protopodite is divided by a fissure into two lobes, a larger (basipodite), with dense rows of bristles on its maxillary surface, and a smaller division (coxopodite). The epipodite is an oblong plate, united by a short stalk to the protopodite.

The second pair of maxillipeds (Fig. 6) has a long, strap-shaped exopodite, like that of the first pair. The endopodite is incurved, and segmented into at least four parts. The dactylopodite or terminal segment is the longest, and is thickly studded with serrate bristles and setæ. There is a small oval epipodite.

The third pair of maxillipeds (Fig. 5) consist of a basal piece (coxopodite) and a long two-branched appendage. The large branch consists of three distinct segments—a long proximal one (basipodite (?) and ischiopodite), a shorter one (meropodite), and a long terminal segment (carpopodite, propodite, and dactylopodite). The exopodite springs from the base of the first segment, and is about equal to it in length. The lower surface of the two terminal joints is covered by numerous transverse rows of serrated bristles, and the end of this appendage is armed with several spines.

The first pair of pereiopods or walking legs bear the great chelæ ("hands" or "shears"). The chelæ are very unequal. Large claw (relatively larger in ♂) smooth, slightly twisted; outer and upper border sometimes marked by a linear crest; several spurs or tuberosities near the articular surface of the dactyle; dactyle shaped like end of pruning knife, its concave inner margin and tooth-like point shutting into a groove of the opposing "thumb." This groove of the propodus is continuous with the well, in which the stopper-like tooth of the dactyle fits. It is bounded by a rectangular process above and a less prominent one below. Tips of fingers barely overlapping. Dactyle sometimes overreaches propodus. Thumb (or extremity of propodus from joint of dactyle) one-third to one-half length "palmer portion" of propodus. Dactyle works somewhat obliquely. Tips of fingers simple. Propodus sometimes hooked.

Small claw (Fig. 3, Pl. XXIV) usually carried bent downward. Fingers nearly equal; three-fourths as long as palmer portion of hand; bent slightly downward and outward; propodus subcylindrical; half as broad as long; tip simple or slightly bifid. Small bunches of setæ on fingers.

Second pair of pereiopods (Fig. 1, Pl. XXIII): The characters of this appendage appear to be remarkably constant and of considerable specific value. They end in a small claw, the fingers of which are provided with bunches of long hairs. Carpus superficially constricted into five rings or segments. First or proximal segment nearly equal to 2+3+4+5. Second, third, and fourth of nearly equal length; fifth equals 2+3.

The third, fourth (Fig. 2, Pl. XXIII), and fifth pairs (Fig. 1, Pl. XXIV) of walking legs are similar to each other, the fifth pair being shortest. Each ends in a short, horny dactyle which is bifid at apex, the primary claw bearing a smaller secondary tooth at base. Propodus little shorter than meros in the fifth pair, and carries numerous bunches of short setæ on its under side. There are also found in this region of the propodus four to six stout appressed spurs.

The first pair of pleopods is specially differentiated in the sexes, and forms one of the most convenient marks of distinction. The first abdominal limb of the male is shown in Fig. 4, Pl. XXIV, and the corresponding appendage of the female in Fig. 5, and the typical appendage in Fig. 6. In the unmodified limb the protopodite carries as usual the two branches—endopodite and exopodite—each fringed with long setæ. The endopodite is a little longer than its fellow and bears a rudimentary secondary branch, which springs from near the middle of its inner edge. In the male (Fig. 4) the appendage is considerably reduced. The exopodite is short and the inner branch a small rudiment. In the female (Fig. 5) the modification has not proceeded so far. The endopodite is here the shorter and has no secondary branch. In the very young forms (first larvæ) these appendages appear to be nearly alike in both sexes (Pl. XXII, Fig. 5).

The uropods or sixth pair of pleopods hardly require special notice (Pl. IV). The endopodite, much the smaller division, is an oval plate, and on its upper side there is a roughened median ridge. The free edges of the plates are fringed with long and closely set plumose setæ.

V.—VARIATIONS FROM THE SPECIFIC TYPE.

We are now ready to consider the remarkable variations which this species undergoes. The form just described was taken as typical, and the largest adults invariably belong to it.

(1) Variety *Longicarpus:* This is the widest departure from the first form or type and is very commonly met with in the brown sponges already noticed. Probably more than 90 per cent of the

individuals found in them belong to this variety. The color variations of this form have already been given in section I.

The rostrum is sometimes wanting, as in the individual from which Fig. 11, Pl. XXII, was drawn. This variation has been noticed in other species and is interesting, since the absence of the rostrum is a constant character in a closely related series of forms, which are placed by Dana in a separate genus (*Betæus*). These variations indicate that the uniform presence or absence of a rostrum is a *specific* and not a generic character, as has already been shown by Kingsley (29). The structural points of difference between the *longicarpus* and the other form lie chiefly in the antennæ and first pair of walking legs. These may be seen by a comparison of Figs. 11, 13, 18, Pl. XXII, and Fig. 2, Pl. XXIV, with Figs. 4, 8, Pl. XXIII, and Fig. 3, Pl. XXIV.

In the first pair of antennæ the aural spine (Fig. 11, Pl. XXII) is scarcely more than half the length of the first segment of the stem. It is blunt and somewhat ovate in shape, as seen from above.

(2) In the other form (var. *brevicarpus*) the aural spine (Fig. 4, Pl. XXIII) has a different shape, and is relatively nearly twice as long. In this case it extends beyond the first segment to two-thirds the length of the second. The second or outer antenna of the *longicarpus* is armed with two spines at its base (Fig. 11, Pl. XXII); an inferior and outer basal spine, and a slightly longer one, the *squamous spine*, articulated to the joint carrying the latter. There is no scale. The basal spine is rather more than one-half the length of the antennal stalk. There may be present a small tubercle on the upper surface of the segment bearing the basal spine, near the articulation.

In variety *brevicarpus* (Fig. 8, Pl. XXIII) the squamous spine is stout and reaches nearly to the end of the antennal stalk. There also springs from its inner and proximal margin an elongate plate or scale, the inner free edge of which is fringed with plumose setæ; scale not quite as long as spine. The inferior basal spine not one-half the length of the squamous spine. There is a rounded or pointed tubercle over basal spine near the joint.

The small chela of the first pair of thoracic legs of the *longicarpus* (Fig. 2, Pl. XXIV) is short and broad. The finger ends in two or three horny teeth or prongs, which interlock those of the opposing thumb. The dactyle bears on its outer surface a tuft of peculiar hairs. The latter are finely serrate and have bent or hooked tips. The carpus is relatively very long, quite as long as the palmar portion of the propodus.

In the *brevicarpus* the small chela is long and somewhat narrower (Fig. 3, Pl. XXIV). Tips of fingers usually simple, but sometimes notched; the peculiar tuft of hairs is wanting. Carpus relatively short; about one-third the length of the palm.

The large chela of the *longicarpus* may also differ noticeably from the *brevicarpus* type. (Compare Fig. 8, Pl. XXIV with the figures on Pl. IV.) Fig. 8 represents a common form of this appendage. The propodus is long, cylindrical, slightly twisted, very smooth, and polished; ends above dactyle in a short spine and below in a rudimentary thumb with claw-like tip. Dactyle overreaches propodus, and its inner margin is not concave, or but slightly so.

These two forms, differing in the particulars just mentioned, would doubtless be considered as two distinct species if only these facts were known. A prolonged study, however, of a large number of individuals, collected both in sponges and from porous rocks on a number of reefs, has resulted in the discovery of a complete series of intermediate links. These connecting forms suggest a number of important questions relating to the causes and significance of variation.

By far the greater number of individuals of this species have the characteristics of the two varieties just described, but about five per cent of the collection made at different points near Nassau present intermediate characters.*

More fully stated, the noticeable points of variation are as follows: (1) The relative length of the antennular stalk and aural spine; (2) the lengths of the antennal spines relative to each other and to the peduncle of the antenna; the presence or absence of a squame or scale; (3) the character of the dactyle and propodus of the small chela of the first pair of pereiopods; (4) the length of the carpus of the small cheliped; (5) the general shape and character of the large

* While the species live, as a rule, in the interior of the green and brown sponges, a few undersized individuals may be found, by careful searching, among the loose blocks of porous coral which are scattered over the reef, and it frequently happens that these individuals possess intermediate characters between the two varieties just described.

claw. (1) With respect to the first point, we meet with a perfectly graduated series between the two extremes (Figs. 11, 18, Pl. XXII, Figs. 4, Pl. XXIII). (2) The same is true of the relative lengths of the antennal spines, the scale, and peduncle (Figs. 11, 13, 14, Pl. XXII). In Fig. 11 there is no evident scale and the spines are nearly equal. In Fig. 14 the spines are markedly unequal, and there is a rudimentary scale. In Fig. 13 this scale is further developed. (3) Great variation is seen in the small chela. The fingers of this claw may each end in two or three prongs, or one in two, the other in three, or the tips of the fingers may be simple or merely notched. The tuft of peculiar setæ on the dactyle may be reduced or wanting. (4) Various stages between the long and short carpus are observed, and (5) slight variations not easily described are constantly seen in the relative size, shape, and other characters of the large chela.

These variations are shown in a general way in Table I. (For detailed measurement, v. Table II.) The fifteen cases here recorded were selected from upward of seventy-five, in a large number of which the variable parts were drawn for more careful comparisons.

TABLE I.—*Showing variations in Alpheus saulcyi and the intermediate stages between the varieties brevicarpus and longicarpus.*

No.	Sex.	Habitat.	Length.	Aural spine.	Squamous spine.
			mm.		
1	♂	Green sponge	29.7	Extends $\frac{2}{3}$ length 2d segment of antennular stalk.	Extends nearly to end of antennular stalk.
2	♀	do	42	To $\frac{1}{2}$ l. 2d segment	Do.
3	♂	Brown sponge	9	do	Do.
4	♂	Green sponge	9.5	do	Do.
5	♀	Rocks; Dix Pt. reef	17	$\frac{1}{3}$ l. 2d segment	Extends nearly to end of antennal stalk.
6	♀	do	10.4	do	Not nearly to end of antennal stalk.
7	♀	do	11.6	l. of 1st segment	Do.
8	♂	Rocks; Hog Id. reef	10	Over $\frac{1}{2}$ l. of 1st segment	$\frac{4}{5}$ l. antennal stalk.
9	♂	do	10	Nearly to end 1st segment	More than $\frac{4}{5}$ antennal stalk.
10	♂	Rocks; Green Key reef.	9.5	$\frac{3}{4}$ l. 1st segment	Nearly to end antennal stalk.
11	♂	Brown sponge	17.5	Nearly to end 1st segment	$\frac{4}{5}$ antennal stalk.
12	♂	do	13	do	More than $\frac{1}{2}$ antennal stalk.
13	♂	Rocks; Dix Pt. reef	9.5	$\frac{1}{2}$ 1st segment	Do.
14	♂	Brown sponge	5.5	do	$\frac{2}{3}$ l. antennal stalk.
15	♀	Reef rocks	11	Nearly to end 1st segment	$\frac{4}{5}$ l. antennal stalk.

No.	Inferior basal spine.	Squame or scale.	Carpus of small chela.	Fingers of small chela.	Remarks.
1	$\frac{1}{2}$ length squamous spine.	Scale as long as squamous spine.	Short	Tips simple; no tuft on dactyle.	Type of var. *brevicarpus*.
2	Less than $\frac{1}{2}$ l. squamous spine.	do	do	Tips simple; no tuft.	v. drawing, Pl. IV.
3	do	Scale nearly as long as squamous spine.	do	do	Claws dull red.
4	do	Scale somewhat shorter than squamous spine.	do	do	
5	Nearly $\frac{1}{2}$ l. squamous spine.	Scale not quite l. squamous spine.	Long	Tips simple; rudimentary tuft.	Combines characters of both varieties.
6	do	Small and rudimentary.	do	Prongs; tuft on dactyle.	
7	$\frac{1}{2}$ l. squamous spine.	do			
8	$\frac{3}{4}$ l. squamous spine.	Rudiment	Short	Tips simple; no tuft.	v. Fig. 13, Pl. XXII.
9		do	Long	Prongs and tuft	v. Fig. 14, Pl. XXII, (outer antennæ from above).
10	More than $\frac{1}{2}$ l. squamous spine.	Rudiment (hardly visible).	do	Propodus ends in prongs.	Dactyle missing.
11		Rudiment	do	Prongs and tuft	Claws reddish orange.
12		No scale	do	do	
13		do	do	do	Type of var. *longicarpus*.
14	Nearly as long as squamous spine.	do	do	do	Rostrum wanting.
15	do	do	do	do	Claws bright blue; dactyle of small chela extends 1mm beyond propodus.

In Nos. 1 to 4 we find little variation from the *brevicarpus* form, which we consider as nearest to the type of the species. From No. 5 to No. 15 the departure from this type is increasingly evident, and in Nos. 12 to 15 we recognize the widest divergence in the varity *longicarpus*.

No. 5 is an interesting case, since it combines the characters of both varieties. The aural spine is rather blunt and extends to one-third the length of the second segment of the antenular stalk. The inferior basal spine is rather less than one-half the length of squamous spine; upper basal spine a rudimentary knob. The squamous spine has a well-developed squame; nearly equals length of antennal peduncle. The "finger" and "thumb" of small chela end in simple, sharply pointed hooks. There is an inconspicuous tuft of setæ on the dactyle. The *carpus is long*. (See Table II.)

No. 8 is also an interesting variation. The antennæ are intermediate in character, between the extremes of the table, while the small chela is of the *brevicarpus* type. There is a rudimentary antennal scale. The tips of the small chela are simple. There is no tuft, and the carpus is short.

In No. 9, which is of the same sex, the same length, and from the same locality as No. 8, the small chela has the characters of the variety *longicarpus*. Nos. 5 to 12, in the middle of the table, show in one way or another intermediate characters between the extremes, Nos. 1 to 4 and Nos. 12 to 15.

VI.—MEASUREMENTS IN MILLIMETERS.

TABLE II.

[Locality: Nassau, N. P., Bahama Islands.]

Habitat	Green sponge.	Green sponge.	Rocks: Dix Pt. Reef.	Rocks: Green Key Reef.	Rocks: Green Key Reef.	Brown sponge.	Rocks: Dix Pt. Reef.
Sex	♀	♂	♀	♂	♀	♀	♀
Number in Table I	2	1		10	6		
Length (tip of rostrum to end of telson)	42	29.7	16	9.5	10.4	11	21
Length of carapax, including rostrum	15	11	7	.....	4.4	4.5	8
Greatest width of carapax	11	.....	4	.....	2.3	2.1	5
Greatest depth of body	11	.....	4	.....	3	.....	.....
Distance between ocular spines	2.4	1.7	.....	.....	.....	.....	.....
Breadth of second abdominal somite	15	.....	.....	.....	.....	.....	.....
Depth of abdomen (with ova)	15	.....	.....	.....	.....	.....	.....
Length of terga of abdominal somites in median line:							
First tergum	2	1.3	.....	.....	.....	.....	.....
Second	6.2	2.8	.....	.....	.....	.....	.....
Third	5.1	3	.....	.....	.....	.....	.....
Fourth	4.1	3.3	.....	.....	.....	.....	.....
Fifth	4	2.6	.....	.....	.....	.....	.....
Sixth	3.8	2.6	.....	.....	.....	.....	.....
Length of telson	5.5	4	.....	.....	.....	.....	.....
Breadth of telson at base	4	3.2	.....	.....	.....	.....	.....
Breadth of telson at tip	2	2	.....	.....	.....	.....	.....
Length of antennular stalk	6	5.2	2	1.8	1.8	1.9	3.3
Length of antennular segments:							
First	3	2.2	0.9	0.9	.....	1	2
Second	2	2	.....	.....	.....	.....	.....
Third	1	1	.....	.....	.....	.....	.....
Breadth of first antennular segment	1.1	1	.....	.....	.....	.....	.....
Length of antennular or aural spine	4	3.7	1	0.7	0.7	0.7	2.3
Width of same at base	1	.....	.....	.....	.....	.....	.....
Length of exopodite of antennule	6	7	.....	2	.....	1.8	.....
Length of endopodite of antennule	9	10	.....	3	.....	2.7	.....
Length of antennal stalk	6.5	5.5	.....	1.5	1.5	1.5	2.8
Length of long segment of same	4.6	4.7	1.6	.....	.....	.....	.....
Greatest width of long segment	1.2	1.0	.....	.....	.....	.....	.....
Length of squamous spine	4.7	4	1.4	1	1.2	0.9	2.1
Length of "squame"	5	4	.....	.....	0.1	.....	1.9
Width of spine and scale at base	1.9	1.7	.....	.....	.....	.....	.....
Length of inferior basal spine	2.2	2	0.9	0.8	0.7	0.8	.....
Length of superior basal spur	0.3	0.2	.....	.....	.....	.....	.....
Width of basal segment	1.1	.....	.....	.....	.....	.....	.....
Length of same to articulation of squamous spine	2.0	.....	.....	.....	.....	.....	.....
Length of flagellum	16	15	.....	3+	.....	5.8	7

TABLE II—Continued.

[Locality: Nassau, N. P., Bahama Islands.]

Habitat	Green sponge.	Green sponge.	Rocks: Dix Pt. Reef.	Rocks: Green Key Reef.	Rocks: Green Key Reef.	Brown sponge.	Rocks: Dix Pt. Reef.
Sex	♀	♂	♀	♂	♀	♀	♀
Number in Table I	2	1		10	6		
Length of propodus of large chela	15	16	.....	5.7	4.5	6	7.7
Length of same to spine at base of dactyle	11	11	5.1	4.4	3.4	4.4	.....
Greatest width of same	5.5	6.1	.....	2.5	2	2.4	3
Greatest depth of same	4	4.6	.....	.....	1.4	2	2
Width of same at spine, at base of dactyle	4.6	5	.....	2	.....	.....	.....
Length of "thumb" of propodus	5.2	6.5	.....	.....	.....	.....	.....
Length of dactyle	4	6	2	2	1	2	.....
Width of same, over tooth	3	3	.....	1	.....	.....	.....
Length of carpus of large cheliped, on upper median line	2.8	2.4	1	0.8	0.6	.....	.....
Length of meros of same	5.5	5.3	3	2.5	2.0	2.0	.....
Greatest width of meros of same	3	2.6	1.7	.....	.....	1.5	.....
Length of propodus of small cheliped	6.7	6	2.2	2	4.5	2	.....
Length of same to articulation of dactyle	4	3.1	1.8	1.8	3.4	1.3	.....
Greatest width of same	2.4	2	0.9	0.8	2	1	.....
Greatest depth of same	1.8	.....	.....	.....	1.4	.....	.....
Length of dactyle of same	3	3	1	.....	1	.....	.....
Width of dactyle of same	1	0.9	.....	.....	.....	.....	.....
Length of carpus of same	2.3	2	1.9	1.5	0.6	1	.....
Length of meros of same	6	5	3	.....	2	2	.....
Greatest width of meros of same	2.7	2.5	0.8	.....	.....	.....	.....
Length of carpus of second pereiopod	7	5.5	.....	1.8	1.7	1.7	.....
Length of first segment of carpus of same	4	.....	.....	0.8	.....	.....	.....
Length of fifth segment of carpus of same	1	.....	.....	0.6	.....	.....	.....
Length of second, third, and fourth segments of carpus of same	2	.....	.....	.....	.....	.....	.....
Length of propodus of same	2.2	2	.....	1	1	1	.....
Length of meros of same	5.1	.....	.....	.....	.....	.....	.....
Length of propodus of third pereiopod	5	4.6	.....	.....	.....	.....	.....
Length of carpus of same	2.8	2.7	.....	.....	.....	.....	.....
Length of meros of same	6.2	5.8	.....	.....	.....	.....	.....
Length of protopodite of third pleopod	6	1.9	.....	.....	.....	.....	.....
Width of same	1.2	1.5	.....	.....	.....	.....	.....
Length of endopodite of same	8	3.5	.....	.....	.....	.....	.....
Greatest breadth of endopodite of same	2	1.6	.....	.....	.....	.....	.....
Length of exopodite of uropod	5.8	4	.....	.....	.....	.....	.....
Breadth of same	4.2	3.7	.....	.....	.....	.....	.....
Length of endopodite of uropod	5	3.7	.....	.....	.....	.....	.....
Breadth of same	3.5	2.9	.....	.....	.....	.....	.....

VII.—THE CAUSES AND SIGNIFICANCE OF VARIATION IN ALPHEUS SAULCYI.

If we consider Nos. 1 or 2 of Table I as representing the nearest approach to the mean of the species, Nos. 5 to 15 must stand for individuals which have fluctuated farthest from the mean.

The individuals given in the table were chosen without reference to sex, yet it appears that nearly two-thirds of the number are males. In examining a larger collection of these aberrant forms I find a still greater percentage of males. There can be little doubt that in those cases the males are in the excess, although I have not tested this point carefully. It is also evident from observation and detailed measurements that the average size of these abnormal individuals is less than one-half that of the brevicarpus type. The brown sponges teem with a population of undersized forms, nearly all of which are aberrant, and none of those which were examined exceeded the length of 17.5^{mm}, which is considerably less than the average for the type.

How far are these variations individualistic and how far are they confined to the race or species as a whole? In other words, is the individual plastic, departing from the standard of the species and becoming different at different periods of its life, or do individuals deviate from the mean of the species, each along its own line? Further, are the variations congenital? While we

are not prepared to answer these questions as fully as we could wish, yet the facts are sufficient to throw some light upon the subject.

We have abundant evidence that there is considerable fluctuation in the life of the individual, as regards the number, color, and shape of pigment cells for instance. In all larvæ of these prawns the external antennæ have a well developed scale, and it is thus clear that this organ may degenerate and apparently disappear, to be reconstructed again at a later period. The variety *longicarpus* (No. 15, Table I) has no "squame," although it is present in the young (Fig. 7, Pl. XXII), and the cases in which the organ is seen in various stages of development (Figs. 13, 14, Pl. XXII) support and illustrate this conclusion. This, however, is not a rule with the species as a whole, as it is in the somewhat analogous case of the loss and subsequent reconstruction of the last two pairs of thoracic legs in the larvæ of Stenopus and Sergestes.

The question as to how far the characters which distinguish such forms as Nos. 1 and 15, Table I, are congenital can only be answered by a careful study of their development. My attention was not directed to this subject while at the seashore, and in this connection some interesting experiments remain to be performed. The evidence we have goes to show that the young in any given case share the peculiarities of the mother, and this is probably true of such details as the right and left handed condition of the large chelipeds. The following examples illustrate this fact: (1) The adult female in this case has the characters of No. 15, Table I. The antennular or aural spine is nearly three-fourths the length of the first antennular segment. The aural spine has a corresponding length in the larvæ of this prawn at the time of hatching. In the adult the fingers of the small chela end in prongs; there is a tuft of peculiar setæ on the dactyle. In the first larva the fingers of the small chela also end in prongs, and there is a tuft of rudimentary setæ on the dactyle. In the adult the carpus of the small cheliped is relatively very long. In the first larva the carpus of this appendage is about one-third the length of the propodus (relatively a little shorter than in the adult). Fig. 11, Pl. XXII, may be taken to represent the mother (rostrum here wanting), and Fig. 17 the young. The small chela of the mother is shown in Fig. 2, Pl. XXIV, that of the young in Fig. 15, Pl. XXII. Another case exactly like this was observed, where the embryo was taken from the abdomen of the female. (2) The adult in this case has the characteristics of No. 2, Table I (var. *brevicarpus*) (Pl. IV, Figs. 1, 2). The larvæ are shown in Pl. XXI, Figs. 1, 2, 3, 8. The aural spine, at first short, is nearly as long as the first antennular segment when the larva is a week old (Fig. 10, Pl. XXII). In both the parent and young the carpus of the small cheliped is relatively short. The fingers of the small chela end in simple tips; there is no tuft on the dactyle (see Fig. 16, Pl. XXII).

These facts indicate that the young share the peculiarities of the parent, but exactly how far the individual may depart from this standard in its own life, or how strictly the law of inheritance applies in all cases, my observations do not warrant a decisive answer. A few experiments could be easily made upon this Alpheus which would throw light on some interesting questions in heredity. The females with ova are easily obtained; the young are readily hatched and kept alive in glass dishes until they have reached the adult state.

In this species the change of environment, due to the adoption of life in sponges, has probably acted as a direct stimulus to variation. These animals tend to vary most along certain definite lines, as, for instance, the relative lengths of the antennular segments and aural spine vary much, while those of the segments of the carpus of the second pair of thoracic legs are practically invariable. Homologous parts vary alike, unless specially differentiated in different ways, as in the chelipeds. There is no diversity of life between males and females, and both sexes vary alike, but aberrant males are probably the more common.

The occurrence of large numbers of individuals showing variations of the same kind, but of different degree, render it plausible at least that the same variations may occur in a large number of individuals simultaneously, but the reason why this or that part has varied most is wholly obscure.

The aberrant forms (variety *longicarpus*) which have adapted themselves to life in the brown sponge thrive and produce young which, in the early stages certainly, share in the peculiarities of the parent. The variety *brevicarpus* is similarly adapted to its environment and its young resemble

it. Has natural selection, then, acted so far as to differentiate the species in more than one direction? There are some facts which favor the view that it has done so, but before the question can be definitely settled we must determine more precisely how far intermediate or aberrant forms represent phases of the individual and of the race. It is not probable that we are here dealing with the hybrids between two originally distinct species.

PART SECOND.

THE DEVELOPMENT OF ALPHEUS.

I. STRUCTURE OF THE LARVA.

(Pl. XLIX, Fig. 174. Pl. LIII, Fig. 196. Pls. LIV–LVII.)

These studies in the embryology of Alpheus begin with the growth of the ovarian egg and the early phases of segmentation and extend to the larval and adult periods. In order that the progress of development may be followed in the light of the structure which the embryo finally attains, we will start with a general survey of the anatomy of the first larva of *Alpheus saulcyi*. A fuller description of the histology and histogenesis of the tissues will be given in the parts which treat of the different organs in detail.

A profile view of the larva as it appears while still inclosed by the eggshell and of one immediately after hatching is seen in Pl. XXI, Figs. 1 and 5, and the brief and insignificant metamorphosis which is required to provide it with the adult characters are illustrated and described in a separate paper (Pls. XXI–XXIV).

Most noteworthy are the large, stalked, compound eyes, the segmented abdomen provided with its full number of appendages, the short, stumpy antennæ, and the swollen chelæ or pincers of the first pair of thoracic legs. At this stage this Alpheus is a *larva*, but in a restricted sense, since many adult characteristics are present. It is a larva, with preparations for immediately assuming the adult state. Some of the *larval* peculiarities are the spatulate telson, the biramous or schizopodal pereiopods (first to fourth pair, inclusive), the rudimentary pleopods, the unabsorbed food yolk, and the uncovered, stalked eyes.

The structural details are now very great, so that it is often impossible to interpret the parts seen in a single section, and it is only by comparing sections made in different planes that the relations of the organs can be successfully made out.

In Fig. 196 (Pl. LIII) the plane of section is nearly vertical and median throughout, except for the posterior half of the abdomen. The supra-œsophageal ganglion, which is usually spoken of as "the brain" (*s. o. g.*), is a complex organ, composed of internal, medullary masses (*punktsubstanz balls*), and cellular tissue which completely invests them. It is made up of the fused ganglia of at least two segments, those of the first and second antennæ. This fusion is complete from the early stages of development, and the relations of the parts are now extremely complex. They are best illustrated by a comparison of the series of transverse sections (Pls. LIV, LV, Figs. 211–219) with those made in a horizontal plane (Pl. LVII, Figs. 238–243), and it will be seen that there are four pairs of fibrous masses in the brain, intimately connected together.

These compact and finely granular masses in the interior of the ganglia of invertebrates were described by Leydig twenty-five years ago under the name of *Punktsubstanz* and later by Dietl (1876) as *Marksubstanz*. As Krieger remarks, the latter name is bad, since it confuses this tissue with the spinal marrow of vertebrates, with which it has nothing to do. It is essentially a *felt* of very fine fibers. We will therefore speak of it as the *Punktsubstanz*, or, to use a more descriptive term, the *fibrous substance* of the ganglia.

The first pair of these, the *anterior or optic fibrous masses* (Pl. LV, Figs. 212–215), are the largest. They are completely fused on the middle line and form a single compact mass, which is slightly constricted laterally (Pl. LVII, Fig. 242, *of.*) and which is divided in front (Pl. LIV, Figs. 210, 211), where it gives off two diverging stems of fibrous tissue (sometimes called *optic nerves*) to the optic ganglia in the stalks of the compound eyes (see also Pl. LVII, Fig. 240 *of.*).

Next in point of size are a pair of large *lateral balls*, which appear kidney-shaped in transverse section (Pl. LV, Fig. 216, *l. f.*). Each is virtually segmented at the lower surface into two lobes (Pl. LVII, Fig. 242, *l. f.*). These lobes are closely united to each other, and by a pedicel or stalk of fibers to the lower posterior extremity of the anterior, optic mass. A third pair of fibrous masses (Pl. LV, Figs. 215, 216, *af.*) fuse with the anterior mass at the same point. Each of these balls is also bilobed, and from them issue the fibers of the antennular nerves. (Pl. LVII, Fig. 243, *n. au.*, also Pl. LV, Figs. 212–214, *a. o.*, *nau.*) The nerve of the first pair of antennæ consists of cells and fibers, which pass to a mass of deeply staining cells (*a. o.*), *the ear*, and to the tissues of the antennular stalk. The fourth pair of fibrous masses (Pl. LV, Figs. 217, 218, *gf.*, also Pl. LVII, Fig. 243) are intimately associated with the last and with the common bridge of tissue (Pl. LV, Fig. 216, *of.*) which unites them all. From these arise the fibrous elements of the antennal nerves, which supply the green gland and the tissues of the appendage (Fig. 216, *n. ag.*). From this same region (Fig. 218, *fo.*) the commissures which surround the œsophagus and unite the brain to the ventral nerve cord also originate (Fig. 220). These commissural bands meet immediately behind and below the œsophagus, where they fuse (Pl. LV, Figs. 222, *ocm.*) and join the ventral chain of ganglia. This last consists of the ganglia of the remaining eighteen segments of the body. Each ganglion is double and is made up of two fibrous balls, united by a transverse commissure, and of a thick envelope of nerve cells. Longitudinal commissures of cells and nerve fibers unite the successive ganglia, which form a double chain. These relations are well shown in Fig. 196 and by the horizontal section (Pl. LVII, Fig. 243). The first six thoracic ganglia are very closely crowded together (Fig. 196, *g.* 4–9) and form what is usually known as the *infra œsophageal ganglion* (ganglia of mandibles, first and second maxillæ, and first, second, and third maxillipeds). The next five ganglia, *g.* 10–14, which are less closely crowded than the preceding, belong to the five pairs of thoracic legs and their segments. The fiber balls of each ganglion are pear-shaped masses, disposed vertically, with the large end of the pear turned toward the base of the appendage. The abdominal ganglia are more widely separated and the longitudinal commissures are consequently more marked (Fig. 196, *g.* 15–20; see also the series of transverse sections, Pls. LV, LVI). The nerves, always difficult to distinguish, owing to the close similarity of their cells to those of the surrounding ectoderm, are best exemplified in the case of the antennular and antennal nerves already mentioned.

The relations and course of the fibers, which are very complicated, are partially indicated in some of the sections. There is a marked transverse commissure of fibers in the anterior half of the large optic swelling (Fig. 213), and at its posterior extremity, where it fuses with the lateral and antennal masses (Pl. LIII, Fig. 198, *gf.*).

The optic stalks or lobes, bearing the compound eyes (Pl. LIV, Figs. 209, 210, and Pl. LVII, Figs. 239–242), consist of an irregular series of fibrous masses, in shape of a distorted letter L. The angle of the letter L is continuous with the fibrous substance of the brain, while its shorter limb proceeds to the compound eye and its longer forms a large swelling in the upper part of the stalk. There is a nauplius eye (Pl. LIII, Fig. 197; Pl. LIV, Figs. 209, 210, *oc.*) borne on a median papilla, which projects downward between the eye stalks. The details of the structure of the eyes are given in Section IX.

The alimentary tract of the larva is a somewhat complicated structure, and the relations of its parts are best understood by reference to sections taken in more than one plane. We can recognize five well-defined portions: the œsophagus, the masticatory stomach, the midgut, the hindgut or intestine, and the appendages of the midgut. These are shown in a semidiagrammatic way in the cut (Fig. 2), and the longitudinal section (Pl. LIII, Fig. 196) and series of transverse and horizontal sections (Pls. LV–LVII) illustrate the structures in more detail.

It is interesting at this point to compare the larva shown in Fig. 196 with the longitudinal section of an advanced embryo (Pl. XLVIII, Fig. 168). In both we recognize the foregut, a tube bent on itself, consisting of the œsophagus and masticatory stomach (*m. s.*). In the embryo the latter is closed on the side of the food yolk. In both we also see a vertically directed fold of endoderm (*f.*, overlying mg^3 in Fig. 196) and behind this the large lumen of the hindgut, which gradually tapers into that of the narrow, tubular intestine. Between this fold on the one hand ard the stomach on the other we find in the embryo an enormous space filled with yolk, which is partially walled in

with endodermal epithelium near the point where it communicates with the cavity of the gut. This in the larva corresponds to the midgut (Fig. 196, *mg.*) and its diverticula.

The œsophagus (Figs. 196, 218–220) is a straight, vertical tube, with very thick walls, which are thrown into longitudinal folds. There is an anterior and posterior fold and two lateral ones, which give to the lumen of the œsophagus the shape of the letter X when seen in transverse section (Pl. LVII, Figs. 241, 242). The walls of the masticatory stomach resemble those of the œsophagus, and the folds of the latter are continuous with the valvular structures of this region. The lateral and median thickenings (Pl. LV, Fig. 221, *p. v.*) at the point where this portion of the stomach passes into the midgut may be regarded as a rudimentary pyloric valve. The pouches formed between the median ventral fold (Fig. 221) and the lateral folds (*p. v.*) correspond to the gastrolith sacs in the crayfish embryo (54), but no gastroliths are found in Alpheus.

The midgut appears in the longitudinal section (Fig. 196, *mg.*) as a short, restricted cavity. It is, however, a spacious chamber, as we see by examining a series of sections made in other planes (Pls. LV–LVII). It consists of seven parts or divisions: a dorsal, unpaired, median division (*mg.* in all the figures), and, opening from this, a pair of anterior lobes (*mg.*^{1}), a pair of posterior (*mg.*^{3}) and a pair of ventral lobes (*mg.*^{2}). All these parts are lined with a peculiar columnar epithelium, composed of endoderm cells, derived primarily from the wandering cells, excepting a part of the median and the anterior divisions, where the endodermal wall is absent or only imperfectly formed. The epithelium of the midgut passes imperceptibly into that of the intestine, since the cavity of the hindgut is in communication with the food yolk from the very early stages of the embryo, and since also the endoderm is formed very gradually and first appears in the region where the hind gut communicates with the yolk. On the other hand, the demarcation between the wall of the masticatory stomach (of ectodermal origin) and that of the midgut (Fig. 196) is most pronounced. Correlated with this distinction is the fact that the foregut is a blind sac and completely cut off from communication with the yolk until very late in embryonic life (Pl. XLVIII, Fig. 168). The anterior lobes contain the remnant of unabsorbed yolk (Figs. 218, 237, *y.*), and in cases where the lining epithelium is unformed, the food yolk is in contact with the brain. These lobes are separated by a median vertical partition (*mp.*), composed of connective tissue and muscle cells, which suspend this portion of the digestive tract to the anterior dorsal wall of the body. In a very late embryo which is about ready to hatch we find that the partition separating the anterior lobes is incomplete. The dorsal half of it consists of a downward-growing fold of endoderm cells, with a mesodermic core. The ventral and lateral walls of these diverticula are devoid of epithelium, so that the endoderm extends itself most rapidly forward, on the dorsal median line, and thence spreads to the ventral floor.

The posterior lobes (*mg.*^{3}) are the first to develop (see Pl. LI, Fig. 185, *mg.*^{3}). They lie to one side of and below the hindgut (Pl. LVI, Figs. 226–230, *mg*^{3}., *gg.*$^{1\text{-}3}$). Up to this stage their position is never dorsal to other parts of the digestive tract. It is from these lobes that the gastric gland or so-called "liver" arises. Each lobe is simple until a short time before the embryo hatches, but in the newly born larva it is divided into three lobules. This division is effected in this manner: The lower median part of the primary lobe (Fig. 228, *gg.*^{1}) is constricted off by the growth of a fold from the side next to the hindgut, downwards and outwards, to form a secondary lobule (*gg.*^{2}). By the constriction of the upper portion in the same way the primary lobe becomes divided into three pockets. The relations of the posterior division of the midgut to the unpaired central portion is best shown in a horizontal section (Figs. 236–238). It seems quite probable that a part of the epithelial lining belonging to the enlarged section of the hindgut is endodermal in its origin, but just how much it is impossible to say.

The ventral lobes (Fig. 224, *mg.*^{2}) are ventro-lateral diverticula from the central portion of the midgut and are completely lined with columnar epithelium.

An examination of the structure of a young Alpheus of this species, ten days old, throws much light on the anatomy of the larva just considered. The alimentary tract has at this time essentially its adult structure. The gastric glands open into it by short ducts at a point just behind the masticatory stomach. They consist of three pairs of lobes or cæca. One pair, corresponding to the posterior division of the midgut (Fig. 226, mg.^{3}), is imperfectly divided into three lobules, as in the early larva. They extend backward, below and to one side of the gut. The two remaining

pairs pass forward on either side of the masticatory stomach to a point about on a level with the first maxillary segment. The ventral is the larger and longer of these, and two lobules are constricted off from it near its extremity. They correspond to the ventral lobes of the midgut (*mg.*[2] cut, Fig. 2). The dorsal pair represent the anterior lobes (*mg.*[1]), which are now entirely withdrawn from the head region, and naturally contain no food yolk. The gastric cæca are all filled with a coagulable fluid which stains feebly in carmine. The gastric epithelium for a short distance behind the point where glands communicate with the stomach has marked histological peculiarities. The internal absorbent surface is increased by folds which nearly obscure the lumen of the tube. The cells are columnar and resemble the glandular cells of the liver and probably have the same origin as the latter. In the masticatory stomach there is a strainer of hairs developed on the ventral and lateral walls which are greatly thickened, as we saw in the larva. The dorsal wall is thin, but there is a large valvular fold on the ventral side.

The vascular system of the adult is already outlined in the larva in all its essential characteristics. The walls of the blood vessels are exceedingly delicate, so that it is not easy to ascertain their distribution by means of sections alone. The heart (Pl. LIII, Fig, 196, H.) is a short tubular chamber, flattened between the dorsal body wall and the enlarged section of the hind gut. It is suspended in the pericardial sinus (*p. s.*) to the body wall and surrounding organs by means of strands of connective tissue (alæ-cordis). The walls of the heart are quite thin, and its cavity is partially divided into three compartments by the growth downward from its roof of two sheets of mesoderm cells (Pl. LVI, Fig. 231, and Pl. LI, Fig. 186).

Of the several arteries which lead from the heart, three, and possibly five, can be distinguished. Posteriorly the heart is continuous with the large *superior abdominal artery*, which traverses the abdomen close to the dorsal wall of the intestine (Figs. 196, 232, 235, *a. s. a.*). Near its origin from the heart, the sternal artery (Fig. 196 shows a trace of this vessel between ganglia 12 and 13, to the left of *pr.*) is given off, and passes directly downward to the ventral nervous system, which it penetrates at a point between the third and fourth thoracic ganglia. This is continued backward under the nervous system and forms the *inferior abdominal artery* (Figs. 229–234, *a. i. a.*) Anteriorly the heart gives off the unpaired *ophthalmic artery* (Figs. 196, 215–229, *op*, *a. op.*), which runs forward to the region of the eyes and brain. It is not an ophthalmic artery, strictly speaking, but from the first, supplies arterial blood to the brain and anterior cephalic region generally. In Figs. 215, 216, it is seen cut in partial longitudinal section, where it evidently communicates with the blood space surrounding this part of the brain. The antennal arteries can not be clearly distinguished in sections, but in a much earlier stage trains of cells are seen at the surface of the egg passing forward on either side of the middle line toward the eye stalks, which possibly represent the antennal vessels.

Besides the sinuses already mentioned, there is a large sternal sinus (Fig. 196, *sts. s.*). This occupies the extensive space between the thoracic ganglia and the alimentary tract and "liver," and, like all other similar spaces, is more or less completely filled with serum and blood corpuscles.

Five pairs of gills are present at this stage. They are developed from simple pouches or folds of the skin on the bases of the thoracic appendages (Figs. 193, 230–233, *br* $^{2-5}$). The outer surface of this primary fold soon becomes divided into a number of secondary folds or gill plates, and in a larva which has moulted twice and is twenty-four hours old, the branchia has the structure shown in Fig. 195. The adult gill is precisely similar to this, except that it has a greater number of plates and more definite branchial vessels. In the early larval stages the skin and especially the branchiostegites (Fig. 193, *bg.*) probably serve as important respiratory organs.

In respect to its muscular system the first larva appears to differ but little from the adult. The flexor and extensor muscles of the abdomen are most prominent (Fig. 196, *mu. f.*, *mu. e.*). The former consists of a double rope of fibers, fused completely together and very much twisted. They extend from the sides of the thorax to the terminal telson (Fig. 227–235, *mu. f.*). The extensor muscles (*mu. e.*) are smaller, but otherwise similar to the latter, both in origin and extent. They lie above or to the sides of the digestive tract. Their attachment to the carapace is shown in Figs. 227, 228.

The next most prominent muscles are the adductors of the mandibles and great chelæ. The former consists of a large band of fibers which pass from one side of the body to the other directly

over the nervous system (Fig. 221, *ad. m.*). Closely associated with it are the muscles of the maxillæ. The large flat tendon to which the adductor muscle of the forceps is attached, is well developed at the time of hatching. It is formed by the infolding of a sheet of ectoderm cells at the point of articulation of the fingers of the claws, and in a plane at right angles to their plane of action. The outer ends of the cells of this infolded sheet now oppose each other and secrete the chitinous tendon, while to their morphologically *inner* ends the muscle fibers are attached.

The connective tissues invest the organs and seem to bind them together and to suspend them to the outer ectodermal wall of the body, but in some cases the ectoderm of the surface is apparently replaced by mesoderm cells, and often muscle fibers appear to be attached to the tergum of the somite (Fig. 196). This may be explained by the intimate fusion of the ectoblast and mesoblast at these points.

The green gland (Pl. LIII, Fig. 198, *ag.*) at the base of the second antenna is a well-defined structure. It consists of a blind tube, which passes up close to the brain as far as the anterior sacs of the midgut, and of a solid, disc, shaped body. The walls of the tube are composed of a single layer of large cubical cells. These thin out at the lower end, and to the outer wall is applied the solid nodular body. Neither at this stage nor at any previous one have I been able to detect an opening to the exterior.

In the adult the tubular portion of the gland grows to very great length, coiling itself in all the available space in the anterior region of the body in front of the mandibles. It surrounds the brain and œsophagus and passes down to the labrum and into the eyestalks. The solid almond-shaped body (probably the end-sac) becomes a spongy mass of tissue. Its function is plainly different from that of the epithelium which forms the wall of the tube and to which the secretive product of the gland is due.

The reproductive organs, or what I regard as such, are difficult to find, owing to their very rudimentary condition. They consist of a small cluster of large cells on either side of the middle line between the digestive tract and the anterior end of the heart (Stage X, Fig. 173, R. O.).

With this sketch of the structure of the larva we are ready to trace the history of development from the earliest stages and to ascertain the manifold changes through which the unicellular egg with its great store of yolk passes, before it attains to the wonderful complexity of the larval and adult forms.

II.—THE ORIGIN OF OVARIAN EGGS IN ALPHEUS, HOMARUS, AND PALINURUS.

(*a*) *Alpheus.*—The ovaries of Alpheus are paired cylindrical bodies which extend between the alimentary tract and dorsal blood vessels, from just behind the eyes to the end of the third or fourth abdominal somite. Owing to the transparency of the skin in this species (*A. saulcyi*) they are extremely conspicuous, giving to the female an intense green or yellow hue, according to the color of the egg (Pl. IV). The oviducts open in the usual way by means of a slit-like valve on the basal joint of the third pereiopods.

In Pl. XXVI, Fig. 11, the condition of the adult ovary is shown, as it appears two or three days after the eggs then carried on the abdominal appendages had been laid. The ovarian ova are ripe by the time the young are ready to leave the shell, and the new ova are laid in a few hours after the hatching of the larval brood. Thus there is a constant succession of young, and females are not commonly found without either attached or large ovarian eggs. The breeding season of this species extends, as we have seen, throughout the entire year.

The structure of the ovary is quite simple (Fig. 11). It is essentially a sac lined with germinal epithelium. The external layer of the sac (O. W.) is muscular and contains numerous nuclei. Between the epithelium and fibrous coat there is a wide space filled with blood. This may be unnaturally large in the preparation owing to the disturbing effects of the reagents employed, but it is not wholly abnormal. The germinal epithelium consists, for the most part, of a single layer of large cubical cells. The nuclei are large and granular, and the cell outlines are often distinct. The function of these epithelial cells is twofold: (1) They give rise to ova; (2) They form the epithelium of the egg follicle.

There is no germogen or polynuclear mass of protoplasm from which the ova are developed, but the eggs appear to originate directly from epithelial cells. The new eggs begin to develop,

while the ovarian lobe is yet crowded with ripe ova ready to be laid, on the ovarian wall next the middle line of the body. The process seems to be as follows: The nuclei of the cells of the germinal epithelium increase in size along a certain tract. The cells grow rapidly and are slowly dehisced or pressed into the cavity of the sac. Each is surrounded by a coat of follicle cells. This is formed by the ingrowth of the germinal epithelium about the egg. Sometimes several ova occupy a common pouch (Ger.) which is separated from the rest of the ovary by sheets of follicular tissue (F. E.), but eventually each egg has a covering of its own. Between very young ova (*e*) no larger than the epithelial cell, and the maturer egg (e^1) every stage can be traced. The yolk appears very early as a fine granular deposit in the protoplasm of the cell.

In this species the development is nearly direct, there being no zoëal stage, and the egg contains more than nine times as much yolk as the egg of *Alpheus minus*, in which the first larva is a zoëa-like form. The materials for the yolk must be derived directly from the blood, and in this form the germinal epithelium is bathed with the blood current. Where there is an enormous food yolk blood must be supplied to the developing ova in more than the usual quantity. This is often accomplished by reëntrant blood sinuses which penetrate all parts of the ovarian stroma, as in the lobster (*Homarus*) and in the cephalopods, which are precocious in development and consequently deposit a great store of yolk in the egg. In the latter the follicular epithelium is folded in a remarkable manner about the egg to increase its nutritive surface.

The germinal vesicle (Fig. 11, G. V.) is filled with coarse chromatin grains, and in the early phases grows relatively faster than the rest of the egg. In the egg, (e,[1] to the left) which is $\frac{1}{300}$ inch in diameter, the diameter of the germinal vesicle is one-half that of the entire egg. The chromatin grains increase in size until there are formed, as in an egg like the last, six or more large masses of chromatin, or nucleoli. The older eggs are spherical; their food yolk is often vacuolated, as in later stages, and they are invested by a single membrane, the chorion, which is a chitenous secretion of the follicular cells.

In the ripe ovary of this Alpheus the mature eggs fill the ovarian sac, except at the lower portion next the middle line, where, as already stated, the young ova first make their appearance. These mature eggs are closely crowded and irregular in shape, and their bulk greatly distends the body of the prawn. The chorion is now fully formed and closely invests the vitellus. The yolk is in the form of spherules, usually fused and always vacuolated in preparations which have been subjected to alcohol and turpentine. In the ripe egg the nucleus was not seen, but it is quite probable that careful sectioning would show that it lay at the surface, as is the case with the ripe ovarian egg of the lobster, which is often left in the ovary, after the bulk of the eggs are laid. We thus conclude that the extrusion of polar cells may be internal, that is, may take place within the ovary, as is sometimes, if not always, the case with *Homarus*.

(*b*) *The Lobster* (*Homarus americanus*).—The ovaries of the lobster consist of two lobes or rods of tissue, united by a short transverse bar. When filled with eggs their color is a dark olive green, except in young females, where the color of the immature ovary is variable. Each lobe is composed of an outer wall, which is a felt of muscle and connective tissue fibers with very small nuclei, and of a loose framework of germinal epithelium, which penetrates all parts of the lobe. The latter is a syncytium and consists of a matrix in which great numbers of small nuclei are embedded. These nuclei, with surrounding protoplasm, give rise (1) to ova and (2) to cells of the egg follicle.

The growth of the ovarian egg from the epithelial nucleus is illustrated in Pl. XXV, Figs. 3, 6. Fig. 6 is from a section through the posterior end of an ovarian lobe of a lobster obtained from the Baltimore markets in January. Fig. 3 shows the central portion of this section greatly enlarged The diameter of the entire section is about twice that of the part represented in Fig. 6, and the oldest eggs lie at the periphery. The germogens, the centers of dispersion of new eggs, lie nearly in the long axis of the lobe. We can therefore trace in a single good section at this stage the development of the egg through every stage, from the indifferent nuclei of the ovarian stroma to the large peripheral ova. The ovary is supplied with blood by means of sinuses which penetrate to all its parts (Bl. S.). The sinuses are definite reëntrant channels with thin membranous walls.

The ovarian tissue (Ct. S.) consists of a fibrous matrix in which numerous oval granular nuclei are embedded. The process of the conversion of the epithelial cells into eggs is shown in Fig. 3. The epithelial nucleus (O, O^2) swells out, becomes spherical, and its chromatin has the charac-

teristic granular appearance of the germinal vesicle of the young egg. The first trace of the yolk (O^3, O^4, O^5) appears in the outer granular layer which surrounds the germinal vesicle. This layer represents primarily the cell protoplasm, in which the yolk is formed. The cell takes on a definite shape and is very early invested with a follicular coat (F. C.). In an egg a little older (O^7) the nucleolus has appeared, and in still older eggs (Fig. 6, O, O^1) a delicate chorion (Ch.) can be seen. This is secreted by the cells of the follicular envelope (F. C.). The growing eggs pass out from the central to the peripheral parts of the lobe in the sheets of stroma between the blood sinuses. Distinct yolk spherules are very early seen (O^7) and are of uniform size, but in maturer eggs (Fig. 6, O, O^1) the germinal vesicle is sometimes surrounded by a central layer of small spherules and a peripheral layer of larger ones. The germinal vesicle is centrally situated and always contains a single excentric nucleolus, besides stellate masses in the chromatin reticulum.*

(*c*) *The Spiny Lobster* (Palinurus).—In the spiny or rock lobster from the Bahamas the ova originate exactly as in Homarus, and the structure of the ovary is essentially the same. There are several nucleoli, as in Alpheus. The ovary is not nearly so richly supplied with blood sinuses as in the cases just considered. This is perhaps correlated with the fact that the amount of yolk

---

* Since the above account was written I have been able to study the structure of the ovary more thoroughly, and the subjoined notes are largely extracted from a preliminary notice on "The Reproductive Organs and Early Stages of Development of the American Lobster." (23.)

The structure of the mature ovary is somewhat peculiar. The free, unextruded eggs fill the lumen of the ovarian lobes. The lobe or tube itself consists of the proper ovarian tissue and the outer muscular wall, which is very thick. The stroma is characterized by the presence of *gland-like structures*, blood sinuses, and immature ova. The glands are in close relation with the growing eggs. They are plaited or folded structures, and consist of a single layer of columnar cells, the boundaries of which are indistinct. The lumen of the fold usually contains a granular residue, but often yolk and degenerating nuclei. It seems possible that these structures are comparable to *yolk glands*, and that their function is to supply the growing ova at this stage with a part of their massive food yolk. Three days after the extrusion of the eggs the glandular cæca have much thicker walls; the rapidly dividing cells are smaller, and their nuclei lie at various levels. In another ovary of about the same age the glands are relatively very large. The columnar cells are greatly elongated, their nuclei lie at the deeper or outer ends of the cells, and the lumen of the gland is often completely obscured. The gland forms a kind of egg tube, abutting upon and partly inclosing the growing egg. The columnar cells stop short at the sides of the egg, so that the glandular cæcum resembles a narrow bag with an egg pushed into its mouth. The glandular cells are directly continuous with those of the follicle. The axial portion of this ovarian lobe is composed of hollow spaces, blood sinuses, and loose stroma, in which very young eggs occur. Degenerating cells occur not only in the stroma, but probably in the developing ova also. In *Peripatus Novæ Zealandiæ* the yolk is described by Lilian Sheldon as arising not only from the egg protoplasm, but also from the follicle cells (57).

When ten to fifteen days have elapsed after egg-laying (eggs in egg-nauplius stage), the gland-like bodies have almost wholly disappeared. The walls of the cæca are shrunken and crumpled, and the latter have been crowded to the extreme periphery of the ovary. The ovary now contains a solid core of immature eggs, stroma, and bloodvessels. This is continuous with radial sheets of similar tissue which extend from the center toward the periphery. The outer and more mature masses of ova are thus divided into more or less continuous, longitudinal bands.

At a still later period (eggs with eye pigment, four to five weeks' old) the glands are present merely as shriveled remnants. Later still (lobster taken August 21; egg embryos in a late stage) there is no trace of gland-like structures. In the ovary of a lobster (taken June 30), with eggs about to hatch, the condition is similar to the last. It is now about eleven months since the eggs were laid, yet the diameter of the largest ovarian ova is only about one-half that of the mature eggs. The ovarian wall is thinner than in previous stages, and in the axis of the lobe there are still sheets of very small, immature ova.

It seems that the bodies which have been described as probable yolk glands are present in the peripheral parts of the ovaries only during the limited period of from two to three weeks after the eggs are laid, and when the organs are recovering from the changes which follow this event. Their structure is quite unlike that of bloodvessels or sinuses with which they are intricately associated, and their relation to the growing eggs seems to imply that they have some function to perform in the nourishment of the peripheral ova. Their short existence, on the other hand, might lead us to suspect that they were more or less rudimentary structures, or that they were concerned with the secretion of the gluey substance with which the eggs are coated at the time they are laid. Their true function, however, remains to be determined.

Ovaries which I have examined, taken in summer (July) from lobsters ("paper shells") which have recently moulted and which do not carry eggs, present very thin walls, and the largest ovum measures in diameter about one-half that of the mature egg. These lobsters have probably hatched a brood the present season and have afterwards moulted. (Compare the ovary of the lobster taken June 30 above.)

Some allowance is to be made for individual difference, but the slow growth of the ovarian egg, which we have traced from the summer when eggs were laid to the following summer when these eggs were hatched, is very noteworthy, and shows conclusively that the lobster is not an annual breeder.

in each egg is very small, although the number of eggs produced by this animal is enormous. At Nassau, Palinurus begins to spawn in June.

(*d*) *Comparison.*—Ishikawa describes very fully the ovaries and ovigenesis of the prawn *Atyephyra compressa* and concludes that the ovum "originates from the inner lining of the ovary and is at the beginning a cell with a nucleus and one, two, or rarely three nucleoli.' The mature egg, according to this observer, has two membranes, one of which is due to the "hardening of the peripheral protoplasm of the egg," while the other (secondary egg-membrane) is secreted by the epithelial cells of the oviduct and added at the time the eggs are laid.

There seems to be an error here in regard to the origin of the chorion. In the Decapod Crustacea it is the rule that the chorion it secreted gradually during the growth of the egg by the cells of the egg follicle. The large glandular cells found in the oviducts of Atyephyra possibly secrete the viscid fluid by which the eggs are attached to the swimmerets, yet this point needs comfirmation.

The chorion was found in the ovarian egg of Pagurus by Mayer (39), who says:

Das Eierstocksei von Pagurus ist in der ersten Zeit seines Bestehens eine echte Zelle mit Protoplasma, Kern und Kern-Körperchen. Später findet eine Einlagerung von Deutoplasma und die Bildung einer Hülle aus Chitin statt. Endlich wird der Kern unsichtbar; das Ei stellt dann eine Cytode vor.

Das fertige Ei verlässt den Leib des Krebses ohne Kern und mit einer Hülle versehen.

This description answers for Alpheus in all essential points.

The ripe egg of the crayfish (*Astacus fluviatilis*) is inclosed by a single envelope, the chorion. According to Ludwig and Waldeyer it is not known whether this is a product of the egg or of the follicle cells. Huxley (26) merely states that "a structureless *vitelline membrane* is formed between the vitellus and the cells which line the ovisac." The ovisacs burst and the ova pass through the ovary into the oviduct. When laid, the eggs "are invested by a viscous, transparent substance which attaches them to the swimmerets of the female and then sets." Here as in other forms the chorion is clearly the secretion product of the ovisac.

In *Cranyon vulgaris* Kingsley (31) finds that the late ovarian ova resemble the newly laid eggs. There is a thin structureless envelope (chorion), but no trace of an inner vitelline membrane.

Ludwig's general statement that the egg cells of all Arthropods are surrounded by a vitelline membrane (Dotterhaut), the product of the egg itself, is certainly erroneous. He divides the egg membranes into *primary egg membranes*, those which are derived from the protoplasm of the egg itself or from its follicle cells, and *secondary egg membranes*, those formed by the wall of the oviduct or otherwise. Balfour, following Van Beneden, restricts the term *vitelline membrane* to structures derived from the protoplasm of the ovum, and *chorion* to those formed by the cells of the follicle or oviduct. In the category of secondary structures would fall also those secreted by special glands, found, according to Ludwig, in Trombidium, Chilopoda, and nearly all Crustacea, and the winter eggs of Daphnia and Tardigrada, which is due to a moult or direct separation of epithelium from the body of the mother.

In speaking of the vitelline membrane Van Beneden and Bessels, in their monograph on the formation of the blastoderm (60), thus define it:

Nous entendons la membrane vitelline dans le sens où M. Claparède l'a si nettement définie dans son travail sur les vers Nématodes: C'est la couche externe du protoplasma de l'œuf, qui, ayant acquis une densité plus grande que la masse sous-jacente, se sépare de celle-ci par un contour net et tranché. Elle est à l'œuf ce que la membrane cellulaire est à la cellule; elle se forme de la même manière.

According to this view the ovum is morphologically a cell, the vitelline membrane is the cell wall.

The origin and growth of the egg in Amphipods (*Gammarus locusta*) agrees quite closely with what takes place in Alpheus and Homarus. According to Van Beneden and Bessels (60) the young ova are at first protoplasmic cells, the nucleus of which becomes the germinal vesicle. The ovarian egg is a cell without a membrane, and in the cell protoplasm refringent vesicles are developed which form the yolk elements. According to these authors the mature ovarian egg consists of a viscous, finely granular, and contractile liquid, which represents the primitive cell protoplasm and holds in suspension the germinal vesicle, and, secondly, of nutritive yolk elements (called by them *deutoplasm* because of secondary origin), which are also suspended in the protoplasm of the egg.

In insects it appears that a chorion is always present in ovarian eggs, while, on the other hand, arachnids possess a vitelline membrane and the eggshell is secreted in the oviduct.

There is no simple rule to express the appearance of egg membranes in a diversified group like the Arthropods, and, considering that these structures are purely secondary to the cell and expensive products however formed, this is what we should expect. Their function is chiefly protective, and where a chorion is present in the ovary a yolk membrane is not developed, but the latter is present, as in spiders, when the shell is a later product. Erdl (15) describes three egg-membranes for the lobster, but it is clear, as Mayer has already shown, that the inner, delicate membrane which has been described for the decapod egg, is a secretion product of the blastoderm.

III. SEGMENTATION OF THE EGG OF ALPHEUS MINUS.

In the small green Alpheus of the southern coast we have a peculiar modification of the usual process of segmentation, which seems to be anomalous.

The fertile egg is pervaded with a remarkably fine reticulum, which incloses yolk spherules of minute and uniform size. The nucleus is central, or nearly so,* and consists of an ill-defined mass of protoplasm, in which a fine chromatin network is suspended. In the next phase (Pl. XXVI, Fig. 14) the nucleus is elongated and about to divide. Division appears to be direct and irregular. At a somewhat later stage the phenomena of the most interest occur (Figs. 12, 13). Each product of the first nucleus has developed a swarm of nuclear bodies (S. S.), which seem to arise by fragmentation. These bodies take the form of spherical nuclei in clear masses of protoplasm. The yolk frequently has a tendency to segment about the nuclear masses, in the same way that it divides about a single nucleus to form a yolk pyramid. This yolk segmentation seems to be normal, but it is very irregular. In one case there were two large segments, which nearly divided the egg in two, besides several smaller ones. Nuclear matter consists either of small particles or of indefinite reticulated masses, resembling the first nucleus (Fig. 14). Clear areas are sometimes found with nuclei which appear to be breaking down. About eight nuclear swarms or clusters are present in the stage shown in Figs. 12, 13. The nuclei vary in size from refringent particles to bodies of ordinary nuclear appearance.

Figs. 25 and 26 represent two sections of one of the clear areas in the same egg from which Fig. 12 was drawn. This clear field has several degenerating nuclei near its border. The largest one (S. C.) is included in both sections. A small chromatin mass with indistinct body lies next it (S. C.^{2}), and other similar bodies occur in different sections. The cell S. C. contains two chromatin balls, and in Fig. 26 (the next section but one in the series) this body appears to be discharging through its broken-down wall numerous minute elements (S.) into the clear field. In Fig. 22 a small protoplasmic area occurs, in which a single nucleus lies. This body is granular and contains a large chromatin ball. Figs. 5 and 23 are also from the same egg. Here we see structures similar to the cell just mentioned. They are surrounded by yolk and consist of a delicate reticulum in which usually one large nucleolus is suspended, besides great numbers of small chromatin particles.

Various stages of growth are here represented, and it might appear at first sight that we have a case of endogenous cell formation. I see no reason to suppose that the eggs examined are abnormal, and I conclude that we rather have in this species a remarkable modification of the usual indirect cell division, attended by an equally remarkable degeneration of nuclear material.

In the last stage obtained (Fig. 29) the whole egg is filled with several hundred very large elements, which are descended more or less directly from some of the nuclear bodies just considered, but the intermediate stages have not been traced. This probably corresponds to stage VI of *A. saulcyi*, at the period just before invagination, but it is quite unlike anything which I have seen in other species. The yolk is now irregularly segmented into blocks or balls, but probably not with reference to these cells.

This case is interesting when we compare it with the degeneration of cells to be described in another section, and from a cytological point of view it deserves careful study.

---

* In single sections the nucleus is strictly central, but whether it is so with respect to the entire egg it is not easy to determine. Minot states that the egg nucleus is always eccentric.—*Am. Naturalist*, Vol. XXIII, 1889.

IV.—THE DEVELOPMENT OF THE EMBRYO.

STAGE I.—SEGMENTATION TO FORMATION OF THE BLASTODERM.

These observations relate to *Alpheus heterochelis* of the Southern States, to a Bahaman form which hatches as a zoëa but which otherwise resembles this species very closely, and to *Alpheus saulcyi*, also the from Bahamas, which has large eggs and a nearly direct development. Except where it is necessary to mention specific differences, these three species will be treated as one form.

In June two Alphei (*A. saulcyi*) laid eggs in an aquarium, but the ova were in each case unfertilized, and for the most part failed to adhere to the swimmerets. One of these eggs, hardened at an interval of five hours after it was laid, is shown in section on Pl. XXVII, Fig. 17. I regard the nucleus of this egg as the female pronucleus. It consists of clear protoplasm, which stains feebly and sends out processes on all sides into the yolk, and of an indefinite chromatin network suspended in it. The massive yolk is composed of corpuscles of uniform size, excepting at the periphery where they are much smaller. Numerous small lacunæ occur, representing parts of the yolk which were soluble in the reagents employed. The chorion, or inner egg-membrane, is transparent, tough, and very distensible. It frequently splits into thin layers when subjected to the hardening and embedding process, thus showing the manner in which it is formed in the egg-follicle. It thus appears that the unfertilized egg of Alpheus is incapable of segmentation.

The first segmentation nucleus has been observed in a few cases. That shown in Fig. 16 is possibly preparing for division. It possesses a fine reticulum; it is lenticular in shape, and granular in appearance, and is surrounded by protoplasm which spreads into the yolk. The once divided nucleus and the next phase with four cells were not obtained in Alpheus, but the latter was seen in an allied prawn (*Pontonia domestica*), and is shown in Fig. 27. One of the three cells present is in the aster stage of karyokinesis and has a well-marked equatorial plate. The third segmentation phase is illustrated in Figs. 9, 28, and 30. In the section through the entire egg, three of the eight cells present are met with, and one of these (x) is shown with greater detail in Fig. 30. A cell in process of division is represented in Fig. 28. In another egg with eight cells present, two are undergoing division in different planes. As before, the cells consist of a chromatin network of various shapes surrounded by a clear protoplasmic body, which sends out processes between the surrounding yolk spheres. It is important to notice that the products of the segmentation of the first nucleus pass gradually and uniformly to the surface of the egg. At this stage they have not reached the surface but are visible through the egg shell. The yolk in these specimens consists of spherules or angular blocks (Fig. 28, Y. S.), which are largest in the center of the egg, and contain very few vacuoles.

The fourth phase of segmentation is attended by the cleavage of the superficial parts of the yolk (Fig. 10) around the nuclei, thus giving rise to sixteen blastomeres or partial yolk pyramids. The division of the yolk proceeds but a short distance below the level of the nuclei, so that all the yolk-pyramids open by their inner ends into the common yolk mass which fills the segmentation cavity of the egg. The base of the pyramid, which abuts on the surface is polygonal in shape, and at its middle point some distance below the surface, the nucleus is seen with its investments of protoplasm. The nucleus is large and granular, and the protoplasm which surrounds it reaches out on all sides into the yolk. We may look upon the yolk pyramid as a cell in the strict morphological sense, its protoplasm being concentrated about the nucleus. The blastoderm or primitive egg envelope arises through the multiplication and consequent reduction in size of these huge yolk elements. The surface has then the usual appearance of a fine mosaic of hexagonal plates or cells, the nuclei and surrounding protoplasm of which lie at the surface.

The fifth segmentation phase is shown in Figs. 15 and 31. The septum between the pyramids extends farther into the yolk, while the nuclei are slightly nearer the surface, and the long axis of each is parallel with it. This particular egg was taken in a period of "rest," but in others the nuclei are in karyokinesis, the division being always radial or in a plane at right angles to a surface tangent.

The segmenting egg of *Hippa talpoides* is shown in Fig. 1 (32-cell stage), and a section of a later phase in Fig. 4. The egg appears to have undergone a total segmentation when seen from the surface, but this is not quite so marked as represented in the sketch. The yolk pyramids

(Fig. 4, Y. P.) agree with those in Alpheus and are probably formed in a similar way. In *Palæmonetes vulgaris* the history of segmentation appears to be essentially the same. The nucleus and base of one of the yolk pyramids of this form is shown in Fig. 24. Here we see that the perinuclear protoplasm has a rayed appearance, being produced in all directions into very delicate threads which ramify among the yolk spherules. Some of these threads moreover unite with a thin septum (Sep.) which forms the boundary wall between two adjacent yolk pyramids.

Segmentation proceeds with a regular rhythm up to the fifth stage, but beyond this it soon becomes irregular. A blastula is thus formed, consisting of a single layer of cells or *blastoderm*, and the inclosed central yolk. All the nuclei reach the surface and take part in forming the blastoderm, so that all the protoplasm of the egg which is at first central or internal, comes gradually to assume in the course of segmentation an external position with respect to the food yolk. The blastodermic cell is the direct descendant of the yolk pyramid. It is improbable that the yolk contains any active protoplasm, excepting that which radiates from the nuclei, and which is descended from the perinuclear protoplasm of the first segmentation nucleus.

Stage II.—The blastoderm and invagination.

The prawn when discovered with eggs in the fifth stage of segmentation (Fig. 15) was kept in an aquarium, and the ova were preserved at intervals of several hours. Thus it has been possible to follow the changes which take place between segmentation and invagination with considerable detail.

The egg represented in Fig. 47 is about 15 hours older than last described (Fig. 15). Cell division, which is now irregular, has become accelerated over a part of the egg so that a germinal area or disk (G. D.) representing the future embryo is formed. The side of the egg shown in Fig. 47 corresponds to that occupied by the germinal disk. In reverse view there are much fewer nuclei. The egg has thus lost its radial symmetry and become two sided. Invagination soon follows this stage at a certain point in the germinal area (G. D.). The superficial cells of the blastoderm (Fig. 48) are about one-third their former size, but they still have the characteristics of the yolk pyramids. The cell is polygonal in surface views; the nucleus is surrounded by yolk and the cleavage planes between adjacent cells (Fig. 38, Sep.) are still present.

This stage is characterized by the passage of large numbers of cells from the surface to the central parts of the egg just before the invagination takes place. This process is well illustrated by a series of consecutive sections (Figs. 38–44) taken from the same egg. In all these sections the cleavage of the yolk can still be seen. Many of the blastoderm cells (Fig. 39, a.) are in different phases of division, the dividing plane being always perpendicular to a surface tangent. It is probable, therefore, that the nuclei with their perinuclear protoplasm, leave the yolk pyramid and pass by amœboid movement into the interior. It is, therefore, evident that while morphologically the yolk pyramid is a cell, the elements which pass into the egg have also the value of cells in a physiological sense. Six nuclei are met with in Fig. 38, one of which has wandered some distance from the surface. In the next (Fig. 39) two cells (a. a^1.) are in the aster phase of division; one (a^2) has passed just below the surface, and another (a^3) is near the center of the egg. These cells (a, a^2, a^3,) are sectioned again in the following figure (Fig. 40). Various phases of the process of migration* are seen in other members of this series. In an enlarged portion of a similar section (Fig. 37) several cells are met with, some at the surface just beneath the shell, and others at some distance below it. The protoplasm about the nucleus has no definite bounds, and is often filled with fine particles of food yolk. It is thus evident that these cells feed essentially like amœbæ, by taking the food directly into the protoplasm of the cell.

The critical stage at which cells begin to pass from the superficial to the central parts of the yolk was obtained in an egg just thirteen hours older than the fifth segmentation phase, shown in Fig. 15. There are about a dozen yolk cells in this egg, and one of these is in karyokinesis. The remainder lie very near the surface, but for the most part are separated from it by a thin layer of yolk spheres. It is thus clear that the migration of cells to the central parts of the egg begins

* In the lobster the primary yolk cells arise by delamination, and as suggested in Section V, this is possibly true of Alpheus.

before all the protoplasm, that is, the nuclei and perinuclear protoplasm of the yolk pyramids, has reached the surface. In the slightly older phase, shown in Pl. XXX, Fig. 46, all the protoplasm which does not pass inward is strictly superficial. The yolk has the same appearance as in previous stages, and, as already noticed, the cleavage planes (Sep.) between yolk pyramids are still met with. Very soon, however, the central portion of the yolk segments into balls or angular blocks (Fig. 46, Y. B.), apparently with reference to these wandering cells. A section through the germinal disk of an egg seven and one-half hours older than that shown in Fig. 47 is given in Fig. 57. The cells in the area of the germinal disk are quite closely crowded, and the superficial segmentation of the yolk is still apparent. We now have a primitive epiblast, or external layer of cells, and a primitive hypoblast, composed of yolk cells which have migrated from the blastoderm.

The invagination stage immediately follows that last described (Pl. XXXI). A slight depression occurs at a point on one side of the germinal disk, where the cells are multiplying most rapidly, and numerous cells pass downward into the yolk. The invagination is nearly solid, and the segmentation cavity is still filled with the great mass of yolk and with primitive hypoblast. In the crayfish (*Astacus fluviatilis*) the invaginate cavity becomes a closed chamber within the yolk (54), and this is eventually converted into the midgut, but in most decapods the pit is very small and the mesenteron is formed independently at a later period. A line drawn through the pit and the middle of the germinal disk marks the long axis of the embryo, and the point of ingrowth is at the posterior end.

The structure of the embryo is illustrated by a series of transverse sections (Pl. XXXI). The cells in the center of the egg represent the primitive hypoblast or yolk cells. The nuclei are large and granular, and sometimes occupy the center of a yolk ball. In Fig. 49 the posterior edge of the embryo is sectioned, and the three following sections (Figs. 50–53) pass through the region corresponding to the invaginate area (Ig.). Fig. 52 represents the entire section, of which Fig. 51 is a part. The pyramidal cells, which form the floor of the depression, contain at their peripheral ends no unabsorbed yolk, but at the deeper ends of the cell, below the level of the nucleus, the cell boundaries are lost, and the protoplasm of the cell blends off into the yolk and ingulfs its finely divided particles (Fig. 50). Numerous cells (Figs. 52–54, b, b^{1-5}) have already wandered from the point of invagination into the egg and a considerable distance forward under the germinal disk (Fig. 54, G. D.). These cells are more or less intimately united by pseudopodal extensions of the protoplasm. A coarse reticulum is thus formed, the meshes of which are filled with yolk. In front of the invaginate cells, the germinal disk (Fig. 55, G. D.) is still one cell thick. At the close of the invagination stage the primitive hypoblast has received a considerable accsssion of wandering cells. This stage is usually described as the "egg-gastrula," in accordance with the theory that it represents an ancestral condition, and that the cavity formed at the surface is the remnant of the primitive digestive tract. The discovery of delamination, the actual separation of the inner ends of the cells of the blastula by karyokinesis before any invagination occurs, as I have described in the lobster, and the occurrence of this or of multipolar emigration in Alpheus, together with the fact that in the typical decapod the invagination has no direct relation to the digestive tract or to to the mouth and anus, point to the view already expressed in a preliminary paper upon the lobster (23), that the invagination stage has no reference to an ancestral invaginate gastrula. It seems to me more probable that the egg with primary yolk cells corresponds to the cœlenterate planula stage, and that these yolk cells, which originate from the blastula and which partially or entirely degenerate, represent the remains of a primitive hypoblast. According to this view the invagination is a secondary process, which became so indelibly impressed upon the ancestors of the Decapods that it has remained in the ontogeny of present forms. The conditions which are found in the crayfish can not be regarded as in any sense general or typical.

Stage III.—Optic disks and ventral plate formed.

This stage (Fig. 58) is characterized by a thickening of epiblast which gives rise to the thoracic-abdominal or ventral plate in front of and around the point of ingrowth, by the simultaneous spreading of invaginate cells below the surface, and by the appearance of the optic disks (O. D.),

two patches of ectoblast on either side of the middle line in front of the ventral plate. When the living egg is examined by reflected light these structures appear as misty white patches separate from each other. (See Fig. 2.)

The principal cell mass is the thoracic-abdominal plate (Fig. 58, Ab. P.), from which the thoracic-abdominal process is developed. The position of the pit (Ig.) is faintly marked by the arrangement of the cells at that point. The optic disks are due to the rapid multiplication of epiblastic cells around definite centers. Each is joined to the ventral plate by a lateral band or cord of cells (L. Cd.), on which the appendages are subsequently budded off. A transverse cord (T. Cd.) soon bridges over the space between the optic disks, thus inclosing a triangular area, which corresponds largely to the sternal region of the adult. The extension of the invaginate cells below the surface is only partially indicated by the shaded nuclei. They advance forward and backward from the point of ingrowth, but principally upward, that is, toward the center of the egg, along the lines joining the optic disks to the ventral plate (Figs. 59, 60). The embryo covers nearly one hemisphere of the egg. It is V-shaped, but the angle between the arms of the V varies much in different eggs. There is a marked contraction of the embryo which takes place immediately after this phase, that is, the area of the surface occupied by the embryo becomes appreciably smaller. A similar contraction of the embryo has been observed in Astacus (54) and Crangon (31). With the extension of the epidermis there has been a corresponding activity among the wandering cells. Their relations are well shown by sections through the entire egg (Figs. 56, 59, 60), in which we can still distinguish the primary yolk cells (P. Y. C.) from the cells derived from the invagination (S. Y. C.). The cells of the first have large, granular nuclei and send out processes into the yolk. The others are smaller and are probably multiplying more rapidly. It soon becomes impossible to find any distinction between these wandering cells. The yolk is irregularly segmented into balls (Figs. 60, 63, Y. B.), inside of which the migrating cells are usually found. The epiblastic cells of the surface, which are the direct descendants of the yolk pyramids, have definite boundaries, but some of the cells of the ventral plate (Pl. IX, Figs. 61, 63) tend to form a syncytium, as already seen, while the wandering cells are independent, free-moving elements.

The lateral section (Fig. 56) passes through the outer edge of the ventral plate, and the next toward the middle line (Fig. 60) encounters a sheet of wandering cells. We see at a glance that the migrating cells pervade the greater part of the egg, and that they pass out in all directions from the region of the ventral plate (Ab. P.). Fig. 59 represents a median longitudinal section through the embryo and entire egg, and Fig. 63 a part of a section highly magnified through the ventral plate and region of ingrowth. The cells immediately below the surface (S. Y. C.) are characterized by large and very granular nuclei, which stain with much less intensity than the superficial epiblast. This shows that they are multiplying rapidly, and the finely divided yolk in their neighborhood shows also that the cell protoplasm is rapidly absorbing food. A series of transverse sections of this embryo is given in Pl. XXXIII. The plane of section in Fig. 61 is oblique and passes in a posterior direction. In Fig. 62 the lateral cords (L. Cd.) are crossed and numerous wandering cells are encountered, while anterior to this (Figs. 68, 69) the optic disks are cut. The optic disks (Figs. 64–67) consist of a single layer of epiblast. Their cells are flat and polygonal, cell boundaries are distinct, and the long axis of the oval nucleus is parallel with the surface. When the cell divides this position is reversed, the plane of division being perpendicular to a tangent at the surface. From the optic disk the eye and its ganglia are developed.

STAGE IV.—THICKENING OF THE OPTIC DISKS AND RUDIMENTS OF THE APPENDAGES.

An embryo a few hours older than the last described is shown in Fig. 72. On the thickened cords of cells (L. Cd.) uniting the optic disks to the ventral plate the traces of two pairs of appendages can be made out—the first pair of antennæ A (I.), and, close to the ventral plate, the mandibles (Md.). Some of the central cells (C. M.) of the optic disk have large, granular nuclei. These mark the area of most active cell division, and form an ingrowth or thickening, which is the rudiment of the optic ganglion.

Glancing at a series of longitudinal sections through this egg (Figs. 70–71, 73–75), we notice

several important changes since the last stage. The ventral plate is more extensive and the wandering cells are more numerous. The primary and secondary wandering cells can no longer be distinguished, but all the cells within the yolk are similar in character. They have large, granular nuclei, and multiply by ordinary karyokinesis (Fig. 75, Y. C^2.). Some pass forward underneath the embryo (Fig. 74, Y. C.) and to other parts of the egg. In Fig. 71 two yolk elements are found near the lateral cord, and in Fig. 70 one is seen just under the optic disk. In Fig. 75 the section is median and corresponds closely with the similar longitudinal section of the last stage (Fig. 59.). The transverse cord (T. Cd.) is seen to consist of a single layer of flat epiblastic cells.

The structure of the ventral plate is shown in detail in Fig. 85, which is a section just in front of the point of invagination. This illustrates the character of the syncytium beneath the surface of the plate and the fine degree of fragmentation which the yolk suffers in the presence of the cell protoplasm. At the surface, the cell walls are quite distinct, as already seen, but as soon as the cells pass below it, the protoplasm extends itself in pseudopodia-like processes and incloses particles of yolk. Under these favorable conditions of nourishment these elements, which must be regarded as the mother cells of the mesoderm and the endoderm, multiply rapidly and spread to all parts of the egg. If this section is compared with that of the invaginate stage (Fig. 54), and with a similar section of Stage III (Fig. 61), it is easy to understand the relations of the ventral plate to the wandering cells, and the way in which the thickening of the plate is brought about. At the second stage comparatively few cells take part in the invagination, and the most of these pass directly into the yolk. But, almost simultaneously with this migration of cells there occurs a migration of cells from the surface of the ventral plate. Thus this becomes thickened and cells continue to be supplied to the yolk. This thickening of the plate is possibly due to cell division in both planes; that is, to delamination and emigration. (Compare cells EC, EC$^{1\text{-}3}$, Fig. 85.)

The process by which the optic disk becomes thickened at this stage is quite similar, although there is no true invagination concerned in it. This is shown by a series of connective sections (Figs. 76–83) passing through the entire disk. The anterior rim of the disk is cut in Fig. 76, and in Fig. 83 the rudiment of the first antenna. This thickening is mainly the result of the migration of epiblastic cells from the surface. After leaving the surface, the cell wall usually becomes indefinite. The relations of the optic disks to the entire egg are seen in Fig. 84. The central yolk is segmented as shown in Fig. 74, and a yolk cell usually lies within the segment.

Stage V.—Rudiments of three pairs of appendages—cell degeneration.

The embryo represented in Fig. 93 is, approximately, three days old (temperature at Nassau 78–80° F.). It occupies nearly one entire hemisphere of the egg, the opposite side of which is covered with flat epithelial cells like those seen at the periphery of the figure. The shape of the embryo proper is nearly that of an equilateral triangle, one angle of which corresponds to the ventral plate, and the other two to the optic disks. A line drawn through the first of these angles and the middle of the opposite side would therefore correspond with the longitudinal median axis of the embryo.

The rudiments of the second pair of antennæ, A (II), have now appeared, and we therefore have present at this stage buds of three pairs of appendages, namely, the first and second pairs of antennæ and the mandibles. All are developed nearly simultaneously, but the second pair of antennæ seem to lag a little behind the rest. In respect to the order of appearance of these appendages, allied species of Crustacea differ slightly. The central parts of the ventral plate (Ab. P.) and optic disks (C. M.) are areas of rapid cell division, and are characterized by the presence of large granular nuclei and by the irregular arrangement of the cells. In all other parts of the egg the superficial cells form a uniform stratum one cell deep. This irregularity is due to the gradual migration from the surface of individual cells in these three places. The first pair of antennæ are closely associated with the optic disks, and the mandibles abut against the ventral plate on either side of the middle line. The appendages start on the lateral cords from definite centers of cell division, and the cells tend to assume a radial and concentric arrangement around each center.

The space between the optic disks is now completely bridged over by a sheet of closely

crowded cells (T. Cd.), and the backward extension of this, and the approximation of the lateral cords has quite closed over the central or sternal region of this part of the embryo (St. A.). Cell outlines are very distinct at the surface in preparations, and they are sometimes well defined in cells which have passed from the surface to parts below it, in both the region of the optic disk and that of the ventral plate (Fig. 80, Ec.), but elements closely associated with yolk are usually amœboid. The nucleus of the epiblastic or epithelial cell on the confines of the embryo, or on the extra-embryonic surface of the egg, has the shape of a flattened, round, or oval disk. Epiblastic nuclei in the appendages and other parts of the embryo, where there is rapid cell division, are angular in consequence of crowding, and deep-lying nuclei are generally spherical.

The arrangement of the embryonic cells of the superficial epiblast in beautiful curves and rings around definite centers—orthogonic systems of curves—is not nearly so pronounced as in the embryo crayfish (*Astacus fluviatilis*), according to the delineations of Reichenbach and Winter. Reichenbach states that in the crayfish the superficial embryonic cells multiply about a given center, like that of the "head fold" (optic disk), or "thoracic-abdominal rudiment," according to definite laws. This was discovered by Sachs in the growing tips of plants. According to Sachs, Reichenbach, and others, the cell nuclei always divide in one of two opposite planes; that is, they either separate along a radius drawn from a given center, thus giving rise to radial strings of cells, or in a plane at right angles to this, producing new strings. Thus there is developed about the initial cell a series of concentric circles and radiating lines of cells. The positions of the equatorial plates of dividing nuclei, which some eggs of Alpheus show in abundance, do not indicate the prevalence of such a law in the earlier stages. The early embryo of Alpheus is much less diffuse than in the crayfish, and the different cell groups soon impinge on each other, and their relations are disturbed.

Several transitional stages between the last two embryos figured (Figs. 72 and 93) will now be examined. The first is represented by three longitudinal sections (Pl. XXXVI, Figs. 88–90), and is about seventy hours old. It is from the same prawn as the segmented egg shown in Pl. XXVII, Fig. 15. These sections give some interesting facts with reference to the rôle of the wandering cells. The first (Fig. 88), which is nearly median, cuts the ventral plate and below it the cells which are migrating from it into the yolk. A continuous layer of cells extends anteriorly to the transverse cord (T. Cd.). In this region a wandering, mesoblastic cell (Y. C.) is nearly in contact with the superficial epiblast. The next section touches the outer edge of the ventral plate (Fig. 89), which is marked by large granular nuclei, and crosses the lateral cord and rudiments of the appendages (A. I, A. II, Md.). The folds of the latter arise through the ingrowth of superficial cells. Here another cell (Y. C.[1]) is close to the outer surface of embryo; another (Y. C.[2]) is in a distant part of the egg and is in the aster stage of karyokinesis; others still (Y. C.[3]) have wandered in a diametrically opposite direction. In Fig. 90 we see still more of these wandering cells, in this instance, chiefly above the embryo.

In the middle of the optic disk some of the large granular cells visible from the surface (Fig. 93, C. M.), are met with, and one of them (Fig. 90, Ec. dotted line extended) has just passed below it.

Figs. 86 and 87 are parts of longitudinal sections of an embryo six hours older than the last. The first exposes the optic disk (O. D.) and gives evidence of the further increase of the latter by the emigration of cells from the surface, and it is quite probable that some of the wandering, mesoblastic cells (Y. C.) have already attached themselves to it. (Compare Fig. 90.) In the next (Fig. 87) the inner edge of the optic disk (O. D.) and the outer border of the ventral plate (Ab. P.) are involved. Here the epiblast consists for the most part of a single layer of cells. Two large wandering elements (Y. C.[1]) are in contact with the surface cells of the embryo in the neighborhood of the appendages.

Fig. 91 is from an embryo twelve hours older than the last. The plane of section passes obliquely through the optic disk, cutting the anterior half of one (to the left) and the posterior part of the other. A study of this section and of the series to which it belongs, shows us beyond a doubt what is the fate of large numbers of wandering cells, present at this time. As has been already shown by preceding figures (see Figs. 73, 88, and others), the cell mass constituting the thoracic-abdominal plate is now the principal source of the wandering yolk elements, and, as has been also shown, they migrate into all parts of the egg, multiply by karyokinesis, and settle

upon the optic disks, the bases of the appendages, and other parts of the embryo. They also pass to the extra-embryonic surface of the egg. In Fig. 91 one of these wandering cells (Y. C.) is approaching the surface, while another (Y. C.[1]) nearly touches it; and in Pl. XXIX, Fig. 34, which represents a portion of a section from a later series (Fig. 106) greatly enlarged, we find two yolk elements (Y. C.) quite at the surface. They are triangular in outline, one of the flattened sides being applied to the surface of the egg. Histologically their nuclei are more granular and stain with less intensity than the nucleus of the ordinary epiblastic cell (Ep.), which appears spindle-shaped in vertical section. But between a cell like that seen in Fig. 91 (Y. C.[1]), where the long axis of the nucleus is at right angles to the surface, or cells like those shown in Fig. 34, where the nucleus is flattened against it and the ordinary epiblastic cell, a variety of transitional phases can be found. This is most clearly illustrated in the next stage.

The egg already described (Fig. 93) shows some important changes. The structure of the optic disks and ventral plate is readily seen in the transverse (Figs. 92, 94, 95) and lateral longitudinal sections (Figs. 96, 97). The optic disk, which in stage III consisted of a single stratum of cells, (Fig. 69), is now a thick cell-mass two-thirds the size of the ventral plate. In it we still distinguish a small area of cells with large granular nuclei (Fig. 93, C. M.), which, as we see in Figs. 96, 97, C. M., O. D., is clearly differentiated. It occupies a position just without (or external with respect to the longitudinal median axis) the center of the disk. The nuclei of surrounding cells are not more than half their size. These large cells do not all lie at the surface, but form a solid mass extending into the yolk. The evidence of karyokinetic figures shows that these cells are dividing, and usually in planes perpendicular to the surface. This results in the crowding of the cells, and also in their migration from the surface to parts below it.

In Fig. 90 there is a cell (ec.) whose nucleus has sunk below the level of the surrounding cells, but the cell protoplasm still reaches up to the surface. Such cases render one cautious in pronouncing positively upon the emigration of cells, but sections like that given in Fig. 94, and the fact that cell divisions seem to be for the most part in one plane, convince me that the thickening is partly, if not largely, due to this cause. In Fig. 95, a large cell, the polar star of which is just below the surface, is delaminating. Cases of this kind were rarely noticed, but were observed at a later stage (Pl. XXXIX, Fig. 102, ec.). That wandering cells attach themselves to the optic disk, there is little doubt. They can be traced in all stages of progress from the region of the ventral plate to the neighborhood of the disk (Fig. 90, Y. C.) until they finally come in contact with it.

The thickening of the optic disk described in Stage III (Pl. XXXIII, Fig. 69), is therefore effected: (1) partly, perhaps largely, by emigration of cells from the surface; (2) partly by delamination; (3) by the accession of wandering cells; (4) by the indirect cell division of the elements constituting the deeper part of the disk.

Chromatin grains make their appearance somewhat abruptly at this stage (Fig. 96, S.[1-2].) and they serve to explain in some degree the peculiar granular nature of nuclei in earlier stages. They originate by the degeneration of cells in the ventral plate and in other parts of the embryo, and probably correspond to what Reichenbach has called in the crayfish "secondary mesoderm cells." Their history has been fully traced and will be discussed in Section VI.

The structure of the ventral plate (Fig. 92) resembles that of an earlier stage (Fig. 85) with the difference that the nuclei are considerably larger and contain from one to several large spore-like masses of chromatin. This cell mass has not increased in bulk at a rate corresponding with the growth of other parts, since elements are being continually subtracted from it and added to the yolk. This loss on the part of the ventral plate is made good not only by cell divisions, but also by continued emigration from the surface (Fig. 98, Ab.).

An embryo six hours older than the last is represented by three longitudinal sections (Figs. 98–100). The optic disks resemble in size and general shape the three pairs of rudimentary limbs. The abdominal fold is not yet formed and the labrum is undeveloped. The stomodæum (Fig. 98, Std.) is just making its appearance as a slight invagination of epiblast on the middle line between the first pair of antennæ. The number of chromatin balls (S) and degenerating cells (S. C.) has greatly increased. We see them in all parts of the embryo. Sporelike nucleoli are seen in cells of the epiblast and are confined to no part of the embryo, but they are most characteristic of the ventral plate and optic disks.

In Fig. 98 several independent chromatin balls (S) are seen in the yolk, and the granular cells of the ventral plate are very marked. A large nucleus of one of the cells (ec.), which contains several sporelike bodies, is very irregular in shape, owing to the pressure to which it is subjected, and it has evidently been crowded down from a level nearer the surface. The cell protoplasm, however, shows that it still belongs to the surface tier of cells. This is also true of the small lenticular nucleus next it on its anterior side. Just anterior to this cell is another (Ec.[1]) which is in the act of dividing in the usual way. It seems probable that had this division been effected one or more of the adjacent cells must have been crowded quite below the surface. It is difficult, however, to always determine whether cells whose nuclei are a considerable distance below the surface do not send up stands of protoplasm to meet it. We find in the ventral plate, independent cells multiplying by karyokinesis, and, as evidences of delamination in this region are rare or altogether wanting, we are convinced that, as in the case of the optic disks, this thickening is largely due to the migration of cells from the surface.

There is at this stage a fairly well-defined sheet of cells (Figs. 99, 100, Mes.) extending forward from the ventral plate on either side. The nuclei are oval or elongated, and their long axes are parallel with the surface, that is, at right angles to the major axes of the superficial epiblast cells. This layer of cells is most marked at the bases of the appendages (Fig. 100, Mes.) and extends from the optic disk on either side to the ventral plate. The question of the origin of these cells is not difficult. They are wandering cells which have settled down on these parts of the embryo. They form a part of the future mesoblastic tissues; exactly what part they play will be discussed later on. They multiply by indirect division and extend into the folds of the appendages, while some, on the other hand, degenerate.

Stage VI.—The egg-nauplius.

The fully developed egg-nauplius is represented in Fig. 111, but before this condition is reached there are several intermediate stages to be considered. A series of longitudinal sections (Pl. xxxix, Figs. 101–105) illustrates the structure of an embryo twelve and a half hours older than the one last described. The thoracic-abdominal fold (Fig. 104, Ab.) can now be recognized, and the stomodæum (Fig. 105, Std.) has the form of a straight, narrow tube, between the buds of the first and second pairs of antennæ. The space between these two structures is filled with yolk fragments, among which are scattered, numerous chromatin particles (S) and cells derived from the thoracic-abdominal fold. The epiblast of the sternal region (Fig. 105, 98, St. A.) is no longer a simple layer, but is slightly thickened. This thickening seems to be partly due to rapid cell division in one plane. The cell nuclei are elongated or wedge-shaped and stand perpendicular to the surface. As will be seen later it is also due to the accession of wandering, mesoblastic cells.

The stomodæum is a relatively long straight tube with very slight lumen, and is surrounded with chromatin grains and scattered cells. It is formed at a considerable distance in front of the point of invagination, and one to two days earlier than the proctodæum.

The thoracic-abdominal fold seems to arise by the sinking down of the epiblast along a definite line. There is thus formed a narrow transverse pocket (Fig. 106, Ab. C.), which is quite deep and perpendicular with the surface. Numerous cells continue to pass from the thoracic-abdominal fold to various parts of the embryo, and to join the sheets of cells (Fig. 103, Mes.) already mentioned. In Fig. 103 the four segments of the embryo are well shown. This section crosses the optic disc (O. G.), the buds of the three appendages, and the edge of the thoracic-abdominal fold. The sheet of mesoblastic cells (Mes.) is most marked opposite the folds of the appendages.

The optic disks are now large masses of cells united by a transverse cord which is thickened slightly on the middle line. In Fig. 102, three cells are met in karyokinesis, one in the abdominal area and two side by side in the optic disks. The former exemplifies the common method of cell division, while the latter is a good example of the less common delamination. As has been already seen, karyokinetic figures of dividing cells are commonly met with in Alpheus at all stages, excepting the species *Alpheus minor*, where the division is at first probably direct. I have seen nuclear figures at the yolk segmentation stage of *Crangon*, also in *Hippa*, *Pontonia* and *Homarus*, and Reichenbach found them in abundance in *Astacus*. Indirect cell division is undoubtedly the rule in

the developing eggs of the Crustacea and probably of all the Metazoa. Since we often study only the rapidly achieved result, the phases of nuclear division may be easily missed.

Fig. 106 is a median longitudinal section of an embryo preserved a few hours later than the last. This shows the thoracic-abdominal fold and cleft (Ab. Ab. C.) previously referred to. The sternal area between the latter and the stomodæum now lies next the egg shell, but soon changes its position (Fig. 125, St. A.), owing to the forward growth of the thoracic-abdominal fold. The labrum, here undeveloped, soon grows backward toward the latter, helping to bend the œsophageal tube and probably slightly altering the position of the mouth (Fig. 125).

The proctodæum arises as a solid invagination of the epiblast, at a considerable distance behind the abdominal cleft (Fig. 106, Pd.), in a stage intermediate between the embryos represented by Figs. 105, 106. A transverse section through the point of invagination is shown in Fig. 126, Pd.

The relation of the embryo to the rest of the egg can be seen in Fig. 108, which belongs to the same species as Fig. 106. Besides the shell, which is unnaturally distended, the egg is surrounded by a delicate embryonic membrane (Mb.). This membrane is secreted early by the superficial epiblast, as shown by the fact that it does not conform with the thoracic-abdominal fold.

Wandering cells (Fig. 108, Y. C.) become gradually less abundant, but still continue to pass to the outer surface of the egg next the epiblast. The transition from the wandering, amœboid cell to the flattened mesoblast cell, lying close to the surface, can be best followed at this stage.

The fully developed egg-nauplius (Fig. 111) is about a week old. Embryos from the same prawn vary slightly in size and in the degree of development, and also in the general character of the cells. In some, the cells are larger and fewer in number, in others they are smaller and much more numerous. The embryo is usually at one pole of the oblong egg. That represented in Fig. 111 is about one-eightieth inch long, and if the entire end of the egg were shown the drawing would be nearly twice as large.

The relation of the embryo to the whole egg can be determined from Fig. 127, where the plane of section is through the long axis of the egg, but through the short axis of the embryo. In the course of development the egg increases appreciably in size and also changes its shape, at first being spherical, but gradually becoming oblong. At this period the long axis of the embryo (using this term to apply to the more obvious embryonic tissues of the egg) is parallel with the short axis of the egg, while in the course of growth the embryo spreads over one side of the egg, until its long axis coincides with that of the latter.

The optic disks have become large oval masses of cells which project from the surface, and may now, for the first time, be appropriately called *lobes*. They represent the eye and eyestalk. The blocks of cells (S. O. G.) in intimate relation with the optic lobes are the ganglia of the antennæ, and represent a large part of the future brain. The appendages are all simple, but a bud soon grows out from the posterior sides of the second pair of antennæ.

The right antenna is already bifid near its tip. A little later it has the appearance shown in Figs. 109 and 110. Rudiments of the first pair of maxillæ (Mx. I.) are also present. The ganglia of the second pair of antennæ are developed in close union with the ganglia of the antennules. Together they form the supra-œsophageal ganglion or "brain." The stomodæum (Std.) appears from the surface as a distinct mass of cells extending behind the labrum (Lb.).

The thoracic abdominal fold, at first vertical to the surface, bends up and grows forward toward the labrum, and a shallow groove which marks the median notch of the telson plate (Fig. 110) is formed at its extremity. The anus passes forward (backward in a morphological sense) from its dorsal position through the median notch until, at a considerably later period, it comes to lie on the ventral side of the fold near its apex. The mass of cells (H.) behind the anus probably represents the heart. Near the mandibles and maxillæ, cells are seen with large granular nuclei. These are cells which have migrated from the yolk to this part of the embryo. Nuclei of epithelial cells are sprinkled over the entire surface of the egg, but increase in number as we approach the embryo.

The section through the entire egg (Fig. 127) shows some of the general characteristics of the egg-nauplius. The thoracic abdominal fold is here cut on a level with the anus, and lies in a wide shallow groove. The yolk is composed of irregular blocks, only a few of which are represented, and contains numerous wandering cells. Some of these (Y. C.[2]) are settling down on the ventral nervous

plate, while others (Y. C. Y. C.[1]) have wandered far and wide through the yolk. The embryo is raised considerably above the general surface of the egg and the shell more closely invests the egg than shown in the drawing. The embryonic membrane is not represented.

Fig. 125 is a nearly median longitudinal section, and shows the relations of the thoracic-abdominal fold, the œsophagus, and the ventral or sternal surface between them. The loose and irregular arrangement of cells immediately below the surface is most marked, and also the granular nature of the nuclei which is such a constant character. Numerous degenerating cells (S. S. C.) are seen near the œsophagus, and amœbiform cells can be traced from the thoracic abdominal fold to the surface immediately behind it.

The structure of this embryo is illustrated more completely by a series of transverse sections (Figs. 114–124), the first two of which (Pl. XLI, Figs. 114, 115) traverse the optic lobes, and the third cuts the brain. The central mass of large cells which was noticed in the optic disks can no longer be distinguished. The lobe (O. L.) is composed of similar cells with granular nuclei, the superficial tier being somewhat the larger and columnar. In the brain the central cells are smaller and stain more intensely than those at the surface (Fig. 116, S. O. G.). Wandering cells (Y. C.) can be traced in their passage from the yolk to the optic lobes, brain, ventral nervous plate, and other parts of the embryo. Between the lateral halves of the brain there is a shallow median furrow (Fig. 116, M. F.). This is continued backward into the much broader and deeper depression in which the convex ventral side of the abdomen fits (Pl. XLII, M. F.). The three following sections (Figs. 117–119) pass through the œsophagus, and the ventral nerve thickening immediately behind it.

About the œsophagus (Fig. 117, Std.) numerous chromatin balls (S., S. C.) are seen in the yolk, and a mass of cells (Mes.) is met with at the base of the appendage and within its fold. These elements are derived from the wandering cells and must be regarded as mesoblast. The fold of the appendage consists essentially of a single layer of cells. Those elements which enter it undoubtedly go to form the musculature of the limb while the cells of somewhat similar appearance, which are derived from the ectoblast, represent the ganglia and nerves. On either side of the œsophagus the yolk has undergone important physical and chemical changes. The yolk spheres or blocks are full of vacuoles and have a corroded and granular appearance, while in contact with the embryonic cells there is a residue of small refractive granules. These vary considerably in size, and some of them stain lightly in hæmatoxylin and represent the last stages in the degeneration of chromatin. The eroded and altered yolk (A. Y. S.) is represented in many of the sections. Between the œsophagus and bases of the antennæ the yolk is absorbed, leaving a protoplasmic reticulum (Fig. 117, Ret.).

In Fig. 118 the mass of cells representing the mandibular ganglion (Md. G.) is sectioned, and in the following figure, the mandibles themselves (Fig. 119, Md.). Numerous cells, both in this and the following sections, are seen in the course of their migration from the yolk to join the ventral nerve-thickening. The latter, which is the rudiment of the nervous system, is at this stage scarcely thickened at all, on the middle line, below the level of the mandibles. Thus in Fig. 121 the buds of the first maxillæ (Mx. I.) are united by the primitive layer of epiblast. To this a single migrating cell has attached itself on the middle line. Migrating mesoblast cells (Mes.) also pass into the fold of the appendage, and others (Fig. 120, Mes.) take up a position against the epiblast of the body wall. The nuclei of the latter stain intensely and become flat, spindle shape in section, and probably represent the nuclei of muscle cells.

The structure of the abdomen at this stage is shown in Figs. 120–123. The body wall of the dorsal side consists of a single layer of columnar epiblast, while the ventral wall is thickened. The hind gut (Fig. 122, Hg.) is a tube, the wall of which consists of a single layer of cells. It is laterally compressed so that the lumen is hardly appreciable. The intervening cells (Mu.) largely represent the rudimentary flexor and extensor muscles of the abdomen. A comparison of Figs. 123 and 125 shows that cells extend from the thoracic-abdominal fold on all sides into the yolk.

The cells at the surface in Fig. 124 have come mainly from the yolk (H.) and are in the position where the heart is subsequently developed. Cells approaching the surface in this region are very clearly shown in Fig. 125 (Y. C., Y. C.[1]), which is a section through a somewhat younger embryo.

The wandering cells, as we have seen, abound in the parts of the yolk nearest the embryo. The

nuclei have the usual characteristics—irregular shape and granular contents. They are surrounded by a small irregular body of protoplasm which does not readily stain and which is often difficult to observe. In Pl. XXIX, Fig. 33, several of these wandering cells are seen greatly enlarged. Sometimes, as here, the perinuclear protoplasm appears to join that of neighboring cells, but in most cases there appears to be no such connection between them.

The endoderm, though not represented in the drawings, makes its appearance as a distinct cell layer at this time. In an embryo a few hours older than that represented in Fig. 125 the endoderm has the form of a narrow sheet of rather large cells, between the yolk and the rudimentary heart, near the body wall. In the space corresponding to the heart, blood corpuscles can already be detected, besides scattered mesoblastic cells. Both the latter and the entoblast are derived from the wandering cells which come out of the yolk.

STAGE VII.—RUDIMENTS OF SEVEN PAIRS OF APPENDAGES.

Fig. 110 represents a phase intermediate between the egg-nauplius (Fig. 111) and the present stage (Fig. 130), and is of special interest for the light which it throws on the history of the wandering cells. The structure of this embryo is illustrated by Pl. XLIV, and Figs. 136, 137, 144, 145. Fig. 137, which represents a section just behind the base of the first antennæ (A. I.), may be compared with Fig. 117. Numerous yolk elements are found in the vicinity of the œsophagus, where, as will be seen (Fig. 134, Mu.), they become speedily converted into muscle cells and somatic mesoblast. In Fig. 136 several wandering cells attached to the body wall, have all the characteristics of blood corpuscles, a deep staining granular nucleus, and a clear irregular cell body. The blood cell and muscle cell are both derived from wandering mesoblastic cells, and in the early stages of their metamorphosis they resemble each other, so that it is not always possible to distinguish them. Undoubted blood cells, however, have already made their appearance.

Figs. 144, 145 show that the yolk is pervaded by a great number of cells. These originated in the way described, chiefly by migration from the ventral plate and thoracic-abdominal fold, and also by subsequent multiplication in the yolk. At this period some of the cells migrate to the pole of the egg opposite the embryo and apparently assist in forming a conspicuous dorsal plate (Dp.). In this embryo they have not quite reached the surface. A structure is eventually formed which reminds one of the "dorsal organs" of various Crustacea. This and the wandering cells will receive further consideration later on.

The embryo of Stage VII is represented in Fig. 130, Pl. XLIV. Figs. 111, 109, 110, and 130 form a consecutive series of embryos, each but a few hours older than the preceding. In the first (Fig. 111) the optic lobes, first and second pair of antennæ, and mandibles are all simple appendages, and are quite similar in general appearance. The abdomen and part of the thorax are represented by a simple fold, the thoracic-abdominal fold. In the second embryo (Fig. 109) the parts are more compact and the second pair of antennæ are forked at their tips. In the third phase (Fig. 110) the optic lobes and abdomen exhibit the most rapid growth. The former are drawn closer together and arch outward from the middle line. The anus is dorsal. The abdomen extends forward until it nearly meets the labrum and has a slight groove or depression at its extremity. All the appendages have assumed a more oblique position with respect to the long axis of the body, and the second antennæ are now the largest.

In the fourth phase (Fig. 130) we see the same changes carried still further. The optic lobes are large convex disks which join each other on the middle line and are intimately united to the brain. The anus is terminal. On at least the first pair of antennæ hairs are developed, although there is not perhaps so marked a contrast between the first and second antennæ in this respect as would appear from the figure. The first and second maxillæ and the first and second maxillipeds are present as rudimentary buds.

The general structure of the embryo (Figs. 129, 131) agrees with that of preceding stage. The embryonic tissues consist of cells of various sizes and shapes, from quite large cells down to particles no larger than the balls of chromatin which are suspended within the nucleus, and from the spherical to the lens-shaped, spindle-shaped, and wedge-shaped forms. Generally all the nuclei agree in containing coarse grains of chromatin or nucleoli. These vary much in size and number in different nuclei according to the condition of the cell. In degenerating nuclei, the chromatin residue is aggregated into fewer and larger masses.

Wandering cells are now scattered throughout the entire egg. They occur in abundance both in proximity to the embryo proper and on the sides of the body walls, and especially in the region immediately behind the thoracic-abdominal fold.

Fig. 131 is a median longitudinal section through an embryo like that shown in Fig. 130. The outer or superficial cells are generally columnar and have distinct boundaries. Their nuclei are spherical, elongate, or wedge-shaped. They divide in both planes, but most commonly in the plane perpendicular to the surface. When we compare this section with the similar one (Fig. 125) of the preceding stage the most striking difference is the great increase in the length of the thoracic-abdominal fold and the ventral thickening of the nervous system. Some of the cells of the latter next the yolk (Mes.) are flattened and spindle-shaped. They have recently come from the yolk and joined the nervous system, and it is possible that these and similar cells represent primitive connective tissue envelopes.

In a more lateral section (Fig. 129) the optic lobe is seen to consist of two portions, a superficial layer of large cells (O. E.) and a deeper layer (G. L.). The first is continuous with the general epiblast over the surface of the body. Its cells multiply in both planes, and some of them pass below to join the deeper layer. The cells of the latter multiply by the usual mitosis and also receive accessions from the yolk. The plane of section passes through the equatorial plate of one of these dividing cells. Some of the cells next the yolk (Mes.) are flattened like those just described in the ventral nervous thickening, but this condition appears to be somewhat transitory. The outer layer of the optic lobe may be regarded as a *retinogen*, since from it, or from a layer corresponding to it, the visual apparatus of the eye is developed, while from the deeper layer or *gangliogen* the optic ganglia of the eyestalk are formed.

A comparison of the transverse sections (Figs. 128, 132–135) with corresponding sections of the previous stage (Figs. 115, 117, 121, 124) shows some interesting changes. The brain is larger and more compact, and some of the cells next the yolk are flattened (Fig. 132, Mes.) and bear a resemblance to muscle or connective tissue cells. They originate from the cells marked Ct. S. in Fig. 116, and come from the yolk. Like the cells already mentioned in the optic lobes and ventral nervous system, they seem to represent a rudimentary perineurium, but, as a well-developed covering of the nervous system is not present until a considerably later stage, they are probably transitory. Fig. 134 corresponds closely with Fig. 117. It shows the section of the œsophagus and of the ganglia of the second antennæ. In the younger stage the ganglion (seen to the left in Fig. 117, at the base of the appendage) is a small, loose mass of cells associated with the surface epiblast, while in the older embryo it is in contact with the wall of the œsophagus, is more compact, and its cells are somewhat differentiated. The central nuclei are smaller and stain most intensely. The œsophagus (Std.) is suspended to the body walls by rudimentary muscles (Mu.), the cells of which are much elongated. They are derived from migrating mesoblastic cells like those seen in the earlier stage (Fig. 117, S. C.), or like the one shown in this figure to the left of the œsophagus. Fig. 137, which is from a stage intermediate between the two just considered, gives additional evidence of this rôle of the wandering cells. Fig. 128 furnishes a very interesting comparison with Fig. 121. In the latter, cells abound in the yolk adjoining the rudiment of the ventral nervous system, which is represented by the primitive epiblast on the middle line. In the older stage scattered mesoblast cells are greatly reduced in number and the ventral thickening is very marked. Cells of recent derivation from the yolk (Mes.) at the base of the appendage can also be distinguished.

In Fig. 133, as in Fig. 124, the plane of section is just behind the thoracic-abdominal fold. Here we recognize a tier or plate of tall, columnar cells (End.), the nuclei of which lie at the deeper ends of the cells or on the side away from the yolk. In the presence of these bodies the food yolk (Fig. 135, A. Y. S.) is absorbed or converted into a granular residue. This layer represents the *entoblast* or the epithelium of the mesenteron already described. Numerous wandering cells are encountered (Figs. 124, Mes.; 135, Y. C.), which take up a peripheral position, and from the first are closely associated with the epithelium of the hindgut. They unite the mesenteron to the hindgut, and it is impossible to say exactly where the one begins and the other ends. Between this entoblastic plate and the surface epiblast (Ect.) numerous cells are interpolated (Figs. 133, 135, Mes.), which are undoubted mesoblast. They are directly continuous with the layer of mesoblast (Fig.

128, *Mu.*) which extends throughout the abdomen between the hindgut and body wall. Mesoblast cells derived from the yolk (Fig. 129. *Mu.*) are also seen underneath the epiblast on either side of the body. The nuclei of these cells stain very deeply, and the cell protoplasm is prolonged into a short fiber or forms an irregular body. In the latter case the cells have the appearance of blood corpuscles.

The heart originates in the mesoblast (Fig. 135, *Mes.*), between the entoblast and outer wall of the body, just behind the thoracic-abdominal flexure.

At this time fibrous substance (punktsubstanz) is first seen in the brain. It appears as two small masses joined by a transverse commissure, in a plane just anterior to the roots of the first antennæ. It is distinctly fibrous and apparently originates from the protoplasm of surrounding cells.

STAGE VIII.—SEGMENTATION OF THE NERVOUS SYSTEM—AT LEAST EIGHT PAIRS OF APPENDAGES PRESENT.

We have two longitudinal sections (Figs. 138, 139) to illustrate this stage. If we compare the latter figure with the corresponding one of the previous stage (Fig. 131) we see at a glance that a long step forward has been taken in development. Between these, I have obtained one intermediate phase, which is a trifle older than the embryo given in Pl. XLIV, and can be best described by showing in what respects it differs from it.

The rudiment from which the nervous system is formed (Stage VII) is a plate of cells extending from the optic lobes to the apex of the abdomen. Anteriorly in the brain (Fig. 132) it is very thick, but gradually thins out as it is followed backward, until it consists of a single layer of epiblast at the very tip of the abdomen. In the phase intermediate between Stages VII and VIII the portion of nervous thickening between the œsophagus, which passes through it, and the thoracic-abdominal fold is partially segmented into cell masses, the primitive ganglia.

The cells of this ectoblastic thickening may be roughly divided into a surface layer, the nuclei of which are large and contain diffuse granules of chromatin, and a deep cell mass with smaller nuclei which stain more intensely. Similarly in the optic lobe we find a thick pad of uniform, deeply stained cells (gangliogen) next the yolk, and separated from this a well-marked surface layer (retinogen) of larger cells. The superficial, epiblastic cells on the inner or ventral side of the thoracic-abdominal fold are large and columnar. The nuclei are very much elongated and closely crowded together, and lie at all levels. This implies rapid cell division in this layer in a plane perpendicular to the surface, and as a result of this, the thickening of the ectoblastic plate in this region, such as we see in the next phase (Fig. 139).

Near the apex of the abdomen there is a transverse zone of very large cells, and the smaller superficial cells adjoining it are arranged in parallel lines. Something resembling this was noticed in Stage VI (Pl. XLII, Fig. 120, *B. Z.*). It corresponds to the budding zone (*Knospungszone*) which Reichenbach figures and describes in the crayfish. He detects it in a very early stage (Stage E, embryo with rudiments of the mandibles, corresponding nearly to Stage V of this paper), and finds that it consists of a transverse zone of cells containing large nuclei at the extremity of the abdomen, below the notch of the telson. From it the segments following the mandibular segment are gradually budded off.

The present stage is characterized by the segmentation of the nervous system and the great development of the optic lobes. The ventral nerve plate is blocked out by lateral constrictions into its component ganglia. There is also a median vertical ingrowth or constriction which tends to divide the plate into a double cord. It is, however, discontinuous at the middle of each block, so that the ventral nervous system consists of a double chain of ganglia, each pair of which are united by a transverse commissure or band of cells, and each ganglion is similarly joined to the one behind or in front of it. Distinct commissures pass from the brain around the œsophagus and unite the former to the ventral nerve chain. The first pair of post-oral ganglia contain two masses of fibrous substance united by transverse fibers as in the brain. The ganglia following these also contain punktsubstanz. It is developed as a small isolated mass on the dorsal side of each ganglion, toward the middle line. As development proceeds these masses increase in size and are gradually united by transverse commissures in each pair of ganglia (Pl. XLVI, Figs. 150, 151, *Pk.*).

A mass of fibrous or granular substance appears in each optic lobe in the gangliogen next the brain. Fibers pass from it to the punktsubstanz of the brain, which sends fibers down to the

circum-œsophageal commissures to the first post-oral ganglia. The fibrous masses unite on either side of the ventral chain to form a double longitudinal commissure. Thus at an early stage the optic lobes, brain, and ventral nervous system are intimately connected by fibrous tissue.

All the segments of the body are now marked off as seen in Fig. 139. The first post-oral segment is the mandibular (g. IV), and following it are the segments of the maxillæ the maxillipeds and the first pereiopod. The second thoracic ganglion lies in the angle made by the thoracic-abdominal flexure. The third, fourth, and fifth thoracic, and the six abdominal segments constitute the thoracic-abdominal fold.

In the superficial parts of the brain large elements are met with which multiply by mitosis, but have a distinct histological character. They consist of a large spherical nucleus containing a diffuse chromatin network, and a granular cell body without definite wall. They are the ganglion cells, which are abundant in all later stages.

The optic lobe consists of two sharply distinguished parts already mentioned, the *retinal* and *ganglionic* portions. The retinogen which forms the eye is a superficial disk of cells resting like a cap on the other part of the lobe, thickest on the outer side of the lobe and rapidly thinning out toward the middle line to a single layer of cells. The nuclei are elongated and wedge-shaped, and cell division takes place commonly in a plane perpendicular to the surface, corresponding to the long axis of the vertical nucleus. The gangliogen consists of a deeper portion next the brain, containing a ball of fibrous tissue, and a part next the retinogen or eye rudiment. Below the thickest portion of the eye the cells have large nuclei, which show a tendency to arrange themselves in rows radiating from the deeper half of the lobe. These large, clearer cells also extend down to the food yolk, and in lateral longitudinal sections (Fig. 138) form the inner stratum of the lobe. The cells which lie between them and the eye, here one cell thick, are smaller and stain intensely (v. Section IX).

The heart (Fig. 139, *H*) is now a broad and greatly flattened chamber between the body wall and endoderm (*End*). It extends forward a considerable distance between the epiblast and yolk, and is continued backward into the superior abdominal artery (*A. a. s.*). It is filled with serum and blood corpuscles.

The endoderm is a more conspicuous layer (*End.*), and the wandering cells are reduced in numbers. They are still seen in all parts of the egg, approaching the body wall, the nervous system, the endoderm plate, and other parts of the embryo (Fig. 139, *y. c.*).

STAGE IX.—EMBRYO WITH EYE PIGMENT FORMING.

A sketch of the embryo at the time when eye pigment has already formed is shown in Pl. XLVII, Fig. 158. The optic lobes are huge pear-shaped masses meeting on the middle line in front and arching outward and backward on either side of the brain. The ocular pigment appears as a thin, dark-brown crescent near the outer surface of the lobe. Pigment is first formed at the posterior end of the lobe nearest the base of the antennules, and spreads upward over its larger convex end. The brain is constricted into two portions corresponding to the antennular and antennal segments.

The segments of the abdomen are faintly marked off at the surface, and the telson plate which overlaps the mouth, is deeply forked at its extremity. (Compare with spatulate telson of the first larva, Pl. XXI, Fig. 9.) The plumose setæ which garnish the posterior edge of the telson are now represented by short stumps.

The first pair of antennæ are stout, simple appendages, tipped with setæ and folded backward along the sides of the body. The second pair of antennæ just inside of the latter, are biramous. They are also hairy at the tips, and the embryonic membranes surround them like the fingers of a glove.

The present stage is illustrated by Pls. XLVI and XLVII. The drawings are made from different embryos, all of which are of the same age, excepting those represented by Figs. 152, 158, 159, and 161, which are a trifle more advanced.

In the first series (Pl. XLVI, Figs. 146–151) the pigment cells are just forming in the eye. They are first developed in the thickest part of the retinogen next the food yolk. A single section, like

Fig. 146, shows the complete history of development of the retinal layer from its one-celled condition toward the median line (already seen at an earlier stage, Fig. 136, Stage VII) to the point farthest from the middle line, where pigment is formed. The fibrous nerve tissue of the ganliogen now consists of three masses, a ball nearest the brain, which is the first to appear, and two smaller masses between it and the retinogen. Huge ganglion cells (*gc.*) are of frequent occurrence, especially at the surface of the eye stalk next the brain. (The details of the development of the eye are reserved for a special section.)

The brain at this time (Figs. 146–148) differs from that of the previous stage chiefly in point of size. It is composed of nerve cells and large ganglion cells (*gc.*), which occur chiefly near the outer surface, and central fibrous tissue. It rests against the food yolk, and in the living embryo it is bathed with a current of blood (B. S.). The fibrous tissue of the brain has the form of a letter H with a wide and short transverse bar. In front of the transverse commissure (Fig. 147, *Tc.*) the fibrous substance is prolonged on either side into the optic lobes; behind, it extends down to the ventral nerve cord, on the inner side of the œsophageal ring (Fig. 148, *ocm.*).

The ventral nervous system, like the brain, is bathed with blood, which fills a large sinus between it and the yolk. This communicates with extensive blood sinuses extending along the sides of the body (Figs. 148–154, *B. S.*). In some cases the food yolk, usually in an altered or finely divided state, is in close contact with the nerve chain (Fig. 157). Cells extremely flattened and spindle-shaped in section, are found in small numbers closely applied to the nervous system (Figs. 152, 157, *pr.*), and forming a rudimentary perineurium. In most cases they are undoubtedly isolated cells, and do not constitute a membrane. They originate from the wandering cells and correspond to cells similar in shape and origin which appear between the yolk and nervous system at a much earlier period (Stage VII, Fig. 131, *Mes.*). The brain and ventral cord are not as yet differentiated from the superficial epiblast, but anteriorly, flattened epiblastic cells begin to appear between the nerve cells and cuticle. Ganglion cells (Fig. 150) also make their appearance in the cord, commonly at either side, close to the surface.

There is direct continuity of fibrous substance in the optic lobes, the brain, and the ventral cord as far back as the abdominal ganglia. In the latter this substance has not been developed. In each single ganglion there is a ball of this tissue which is united to its fellow in the same segment by a transverse commissure (Fig. 151), and to the preceding and following ganglion by longitudinal commissures. It is as a rule completely inclosed by the ganglion cells, but is separated from the yolk or blood sinus often by a unicellular layer (Fig. 150), and in the antennular and antennal segments of the brain (Figs. 147, 148) the cells next the yolk are discontinuous. In the circumœsophageal cords the fibrous tissue also is without a cellular cortex on its inner or central side (Fig. 149, *fs.*). With slight changes these relations are maintained in the hatched larva (see Pl., LV., Figs. 220–222). The foregut is at this time a tube with definite walls and wide lumen (Figs. 148, 152, *fg.*). At about its middle it is bent abruptly backward on itself in an acute angle. The first portion, leading from the mouth to the angle, is the œsophagus and is directed forward; the hinder blind end of the tube lies in nearly a horizontal plane, and represents the masticatory stomach. The walls of the foregut consist of a single layer of columnar cells with large nuclei. They end abruptly next the yolk, but the cavity of the tube is screened from the latter by a thin membrane of flattened cells. A sheet of elongated or spindle-shaped cells surrounds the wall of the foregut and extends over the nervous system (Figs. 148, 149, *Mes.*), while just below the œsophagus and behind the mouth a bundle of elongated cells grows over the nerve cords to the roots of the mandibles representing the adductor muscles, which become so prominent in later stages. These relations are easily deciphered in the structure of an earlier embryo (Stage VII, Fig. 134), where we have already seen muscle and connective tissue elements, derived from the wandering cells, extending from the œsophagus to the epiblast of the body wall.

Wandering cells also pass into the blood sinuses from all parts of the egg, and become converted into blood cells and connective tissue elements. In Fig. 148 we see two such cells on the edge of the blood stream, and in Fig. 152, (*yc.*) several of these bodies are in contact with the blood current on the side of the egg opposite the embryo. The relations of the epiblast, wandering cells and blood corpuscles in this part of the egg are seen in detail in Fig. 161, where a single large wandering cell is already half submerged in the blood. The various other drawings illustrating this stage (Figs. 154, 155, 160, *yc.*) point to a similar fate for a portion of the wandering

cells. This subject of the rôle of the wandering cells in Alpheus is one of the most difficult and at the same time the most interesting which has been met with in the study of its life history, and a full discussion of it is reserved for another part of this paper (Section VII).

A new structure, the carapace (Figs. 148–151, 160, *cp.*), is seen for the first time at this period. It takes the form of a lateral longitudinal outgrowth of ectoderm on either side of the body in the region of the thorax. These longitudinal folds represent the branchiostegites, which form the outer wall of the branchial cavity. In Fig. 160 the structure of the rudimentary carapace and the way in which it originates is very clearly shown. The epiblast cells at the surface multiply and the cell protoplasm is prolonged downward into long strands or spindles. Meantime the ectoblast is pushed outward along definite lines and the spindles of one side of this fold unite with those of the side opposite, thus forming a framework of transverse beams or pillars. Blood enters the fold, which thus becomes a respiratory organ. This structure is essentially maintained up to larval life (v. Fig. 195).

The hindgut or intestine (Figs. 150, 157, *Hg.*) has a considerably larger lumen than in the preceding stage, but its histology is essentially the same. The walls are composed of a single tier of large columnar cells. The cell protoplasm is granular, and projects into the lumen of the tube, and the cell wall is usually distinct. There is an outer investment of mesoblast as in earlier stages, which is closely associated with the surrounding cells of the developing abdominal muscles (Figs. 150, 160, *mu. f.*). The muscle fibre appears as an outgrowth of the cell protoplasm of the muscle cell. The nucleus elongates until it becomes rod-shaped. The fiber is homogeneous, nonstriated and stains feebly in borax carmine, but not at all in hæmotoxylon. The intestine communicates with the midgut or the cavity which contains the great mass of food yolk, and with the exterior by the anus, which is on the under side of the telson plate opposite the labrum.

Fig. 157 shows the continuity of the epithelia of the hind and midguts, and illustrates in a very satisfactory manner the origin of the endoderm. Histologically the entoblastic cells resemble those of the adjoining epiblast, and it is impossible to draw a sharp line between them. The endoderm cells are vesiculated, have less definite boundaries, and extend pseudopodia-like processes into the yolk. The endoderm begins near the point marked *vac.* Fig. 157. Here the lumen of the tube enlarges, and the endoderm extends forward over the flexure of the nerve cord and upward over the sides of the body. Posteriorly it is separated from the body wall by the blood sinus which represents the heart and its arteries (*H*). The yolk next the endoderm is eroded and granulated. The formation of the endoderm thus begins near the abdominal flexure, in the egg-nauplius stage, at the point where the hindgut communicates with the cavity of the mesenteron, and advances gradually forward on all sides. It is composed of cells (Fig.157, *y. c.*) which migrate from the yolk and assume an extreme peripheral position with respect to it. They eventually acquire cell walls, unite and inclose the yolk which they continue to feed upon, apparently by first producing chemical changes in it and then absorbing its particles. In the early stages the mother cells of the endoderm and mesoderm can not be distinguished with certainty. However, since the endoderm originates as a distinct epithelial layer behind the ventral plate, and thence spreads forwards, slowly walling in the mesenteron, it is obvious that the bulk of the anteriorly wandering cells are mesoblast.

The extensive blood sinuses which are now present have already been mentioned. In the angle between the optic lobes in front, there is a large blood space (Fig. 152, *b. s.*), and blood passes from the heart upward and forward nearly around the egg in a thin irregular stream between the skin and food yolk. Mesoblast cells grow forward from the abdominal region and line the outer sides of the endodermal wall, and extend upward to a thin sheet between the yolk and the epiblast. Endodermal cells coming from the yolk attach themselves to this layer. The pulsatile chamber of the heart is not a very definite structure at this stage. It lies above the endoderm, nearly opposite the angle of the thoracic-abdominal fold. Its walls are delicate, and appear in sections as thin strands of mesoderm cells. The nuclei are elongated and the cell protoplasm is produced into long processes. The pericardial space surrounding it is filled with blood.

In Stage VII (Figs. 144, 145, *Dp.*) we noticed an extraordinary migration of wandering cells to the pole of the egg opposite the embryo. These cells eventually reach the surface and reinforcing the primitive epiblast, give rise to a conspicuous dorsal plate, which is shown in Fig. 153 (*Dp.*). This is from an embryo intermediate between Stages VIII and IX, in which eye-pigment

is not yet formed. The plate is slightly thickened at its center, where there is an inconspicuous pit marking the point of ingrowth. As the invaginated cells pass into the yolk they degenerate, giving rise to spore-like particles which spread in incredible numbers through a large part of the egg. Some of the wandering cells in this region doubtless degenerate before reaching the surface. A part of a similar section is shown in more detail in Pl. v, Fig. 36. The particles vary considerably in size, stain uniformly and intensely and the yolk about them is granular or finely divided.

At a corresponding stage in the lobster (*Homarus americanus*), I have observed a large diffuse patch of cells which probably answers to the structure just described. In this case the embryo rests on the side of the oblong egg and the cell plate is at one end of it, at a point about 90° behind the embryo. This position seems to be quite constant, while in Alpheus the plate is nearly opposite the embryo, at the stage when it is most conspicuous.

Stage X.—Embryo with eye-pigment strongly developed and the posterior lobes of the gastric gland forming.

All the thoracic limbs and the sixth pair of abdominal appendages are present in a rudimentary condition. The abdomen has grown forward until the tip of the telson now extends beyond the optic lobes. The embryonic telson is fringed with seven pairs of setæ, and resembles the larval telson, except that the median notch is deeper. Seen from the exterior the eye-pigment has the form of an oval disk.

The longitudinal section, Pl. xlviii, Fig. 168, shows most of the important changes which have occurred since the last stage. These chiefly concern the eye, the nervous system, and the midgut.

The ectodermal pigment cells (retinular cells) of the retinogen have spread inward until they cover its whole inner convex surface (Pl. xlviii, Fig. 167). Near the outer surface of the eye the crystalline cone mother cells (*cc*) can be recognized, and between the eye and the ganglia of the optic lobe there is a narrow space which communicates freely with the blood sinus (*B. S.*) on the outer side of the lobe. Wandering cells are frequently seen near this blood sinus, and in the space between the eye and ganglia flattened cells also occur, which find their way in thither from the yolk. In the optic lobe another fibrous mass has developed near the eye (Fig. 164–7). In horizontal section (Pl. xlvii, Fig. 159) the relations of the fibrous tissue of the brain and optic lobes is clearly shown. In each lobe there is a chain of four fibrous masses united by a stalk of fibers to the anterior or optic swelling of the brain (*of*).

The structure of the brain (Figs. 159, 169, 170) begins to approach in complexity that of the larva, which was described in the first section of Part ii of this paper. The lateral fiber-balls, so conspicuous in the later stages have now appeared (Fig. 159 and Pl. xlix, Fig. 174, *lf.*). They are developed in close union with the large central fibrous mass, which supplies the optic lobes, and probably belong primarily to the antennular segment. Below this and nearer the middle line there is a less definite fibrous center (*gf.*) which supplies the antennal segment. With this, the œsophageal commissures are directly continuous (Figs. 171, 174 *ocm.*).

The complete chain of ventral ganglia can be seen in Fig. 168. This section is not perfectly median, but cuts a fiber-ball of each ganglion. The skin or hypodermis is now differentiated from the nerve elements and consists of a thin layer of flat cells. The fibrous masses of the ganglionic chain are also imperfectly surrounded by peculiar cells, the nuclei of which are spindle-shaped in section. These also occur in the brain, and in either case must be regarded as metamorphosed ectoderm cells, or more probably as intrusive mesoblast. A transverse section of the nerve cord in the thoracic region is shown in Fig. 172, and corresponds very nearly in plane of section with Fig. 151 of the last stage. The fusion of the ganglia is now more complete, and the fibrous balls and commissure are relatively larger. (Compare with this, Fig. 176, a section of the thoracic ganglion of the larva.) In the abdominal ganglia the fibrous elements have essentially the same relations, but lie at a deeper level, being separated from the adjoining tissues by at most a single layer of nerve cells. In Fig. 168 we see that the yolk comes in close relations with the nerve cord behind the œsophagus to the endodermal fold (*f*) near the point of union of the mesenteron and hindgut. Wandering cells approach the cord and become flattened against it, as already observed in much earlier stages.

The two divisions of the foregut, œsophagus, and masticatory stomach, have the relations already described. The wall consists of a single layer of tall columnar cells. In the masticatory division the wall has begun to thicken next the yolk screen, its cells being cuneiform, and the nuclei elongated and crowded below the surface. From the anterior wall, muscle or connective tissue cells extend forward under the brain.

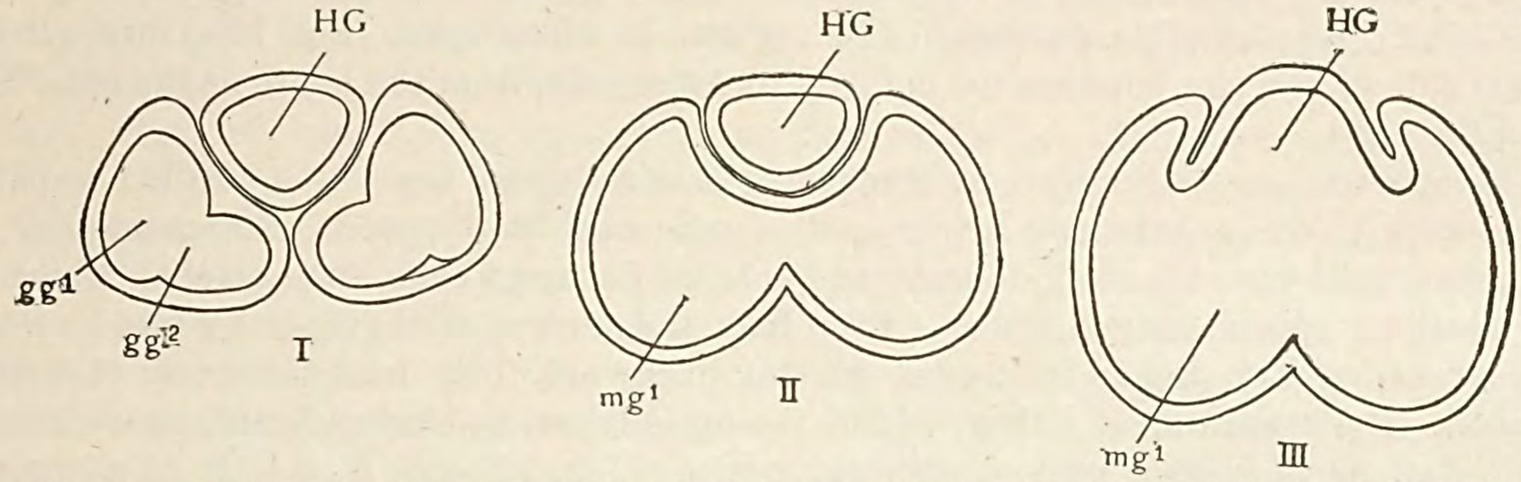


FIG. 1.—Diagrams of transverse sections through the alimentary tract of an embryo of *Alpheus saulcyi* which is nearly ready to hatch, to show the origin of the gastric gland from the postero-lateral lobes of the midgut. Section I cuts the hindgut and lobes of the "liver," Section III the hindgut where it merges into the mesenteron. gg^1, gg^2, Secondary lobules of mg^1; *HG*, hindgut; mg^1, postero-lateral lobes of midgut.

The development of the mesenteron can be understood by reference to Figs. 162–165, 168, and 185. The endodermal epithelium spreads by the division of its own cells and by accession of cells from the yolk, both forward over the nervous system and upward against the sides of the body. This is shown in the series of horizontal sections (Fig. 162–165). Fig. 168 which is from an embryo a little more advanced, shows that the endoderm is rising from the nervous cord near its point of flexure, into a transverse vertical fold. Simultaneously with the upward growth of this ventral fold, two dorsal longitudinal folds grow downward, and finally unite with the ventral fold and with each other, thus constricting off from the alimentary tract two lateral pouches, the primary lobes of the "liver." The folds grow forward and the constriction proceeds gradually with the growth of the embryo. This process is illustrated by the diagrams (Fig. 1) which were drawn from an embryo near the point of hatching. The histology of the endoderm as shown in Fig. 173, is essentially the same as in the previous stage. The cells are prismatic, and the nucleus spherical, and, as in all stages, filled with numerous nucleoli or chromatin balls. The cell walls are very delicate and the protoplasm often contains large vacuoles.

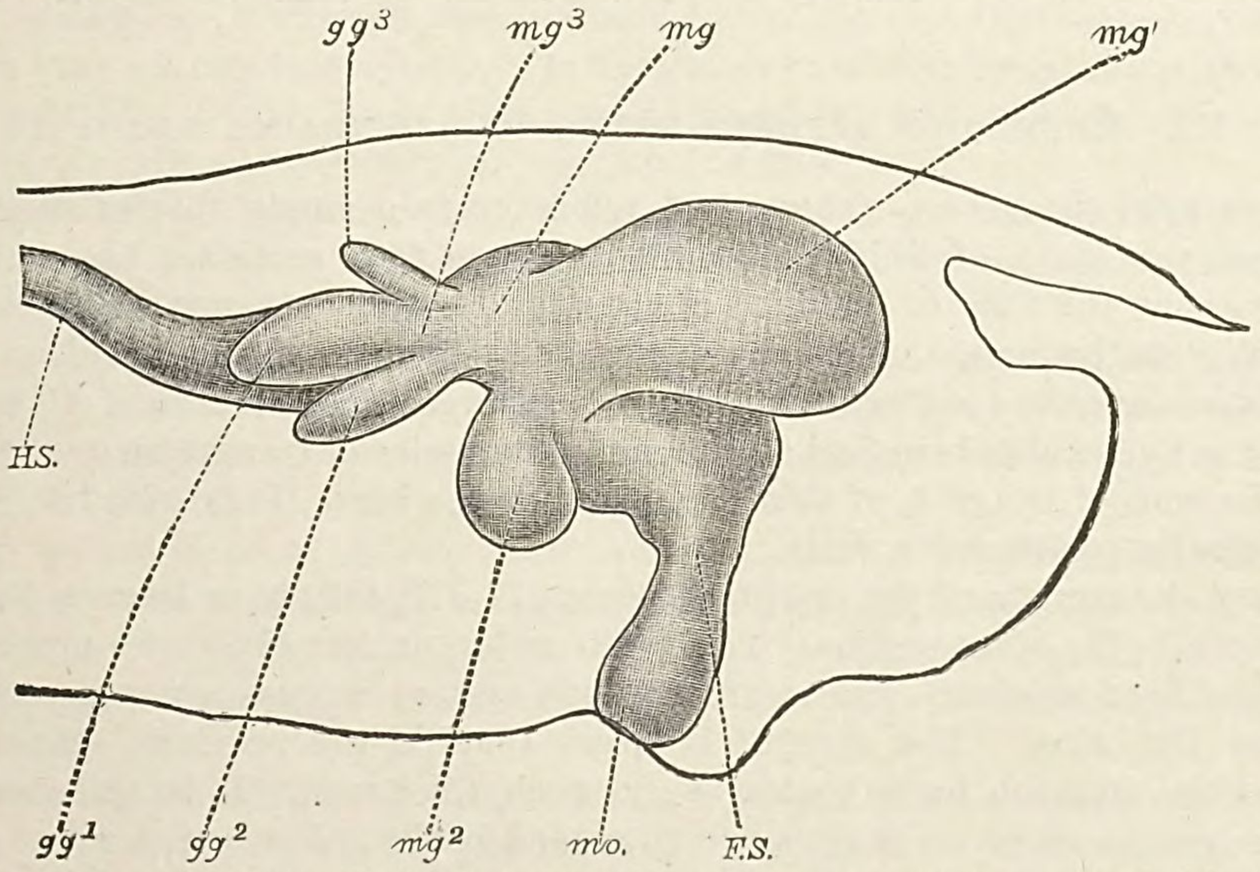


FIG. 2.—Semidiagrammatic representation of the alimentary tract and its appendages in the first larva of *Alpheus saulcyi*. The middle line of the body is also shown. *FS*, foregut; *gg* 1–3, secondary lobules of postero-lateral lobe of midgut; *HS*, hindgut; *mg*, midgut; *mg* 1–3, anterior, lateral, and postero-lateral divisions of midgut; *mo*, mouth.

Wandering cells still occur in all parts of the yolk, though in far less abundance than in earlier stages. We find numbers of them moving toward the periphery, or next the body wall to take part in forming the endoderm. The epiblast is conspicuous in Fig. 168 just in front of the optic lobes. This corresponds in position with the dorsal plate (Fig. 153 *dp.*), and is probably a remnant of it. The small clusters of cells beneath it and the degenerative products which occur near them, probably also represent the remains of the great swarm of degenerating chromatin particles which was formerly present in this region. A blood space (Fig. 168,) now extends over the dorsal side of the egg between the epiblast and the yolk, from the heart to the optic lobes and region of the head.

Anteriorly we can distinguish in transverse section three vessels—a median impaired one, which answers to the ophthalmic artery, and a pair of lateral vessels, the antennary arteries. The vascular walls are extremely delicate and contain flattened cells, the nuclei of which in longitudinal sections appear almost linear. Seen from the surface of the egg the blood vessels have the appearance of two bands of tissue, passing backward from near the point of union of the optic lobes. Between and at either side of the optic lobes, and beneath and to each side of the brain, we find blood spaces packed with corpuscles (Figs. 166–169, *B. S.*) It is not possible, in most cases, to distinguish at this phase true sinuses (veins) from arteries. The structure of the heart is shown in Figs. 164 and 168 (*H.*), and is essentially the same as in Stage IX.

In Fig. 173 there is a small solid cluster of peculiar cells (*R. O.*) on either side of the alimentary tract, between it and the heart. This I regard as the rudiment of the reproductive organ. The cells are clearly differentiated from the surrounding cells. The nuclei are very large, spherical, and stain lightly and diffusely. They are enveloped in a capsule of mesoderm cells, like those forming the walls of the heart, and they originate from similar elements. In Stage IX (Fig. 157) these cell masses were first recognized. They are then distinct from the surrounding elements, and the nucleus contains a very delicate reticulum. Each cell cluster is so small that unless the sections are uniform and complete it is very easily overlooked. The muscles have developed in various parts of the body (Figs. 168, 171, 172, *mu.*, *mu. f.*, *mu. e.*, *g. m. a.*), but most striking at this stage are the great flexor and extensor muscles of the abdomen.

The green gland (Fig. 170, *A. G.*) is another organ which we now meet with for the first time. It is an irregular tube, closed at both ends, and lies at the base of the second antenna, extending up a short way between the body wall and brain. In the previous stage all the tissue at the root of this appendage is very loose and reticular, and no lumen can be seen. I have been unable to detect any opening of the gland to the exterior, nor should we expect to find any, since, as we have already seen in Section I, there is none in the larva. It must be regarded as a mesodermic structure.

STAGE XI.—EMBRYO OF ALPHEUS HETEROCHELIS NEARLY READY TO HATCH.

The later stages (Stages VI–X) have had reference to a single species of Alpheus, namely, *Alpheus saulcyi*, the larva of which is described in the first section. The embryo of *Alpheus heterochelis* at about the time of hatching is considerably less advanced than the embryo of the first species at a similar period, and will serve in many respects as a convenient connecting link between the larva described in Section I and the last stage. The embryo of *Alpheus heterochelis* is represented by a longitudinal vertical section and by a series of transverse ones (Pls. L, LI). The longitudinal sections of Stage X, of this stage, and of the larva (Figs. 168, 180, 196), form a very interesting series for comparative study.

The eye and the ganglia of the eye stalk (Figs. 177–179, 187) have become highly specialized, and closely resemble the adult organs. The brain is larger, but shows no new structures which have not already been noticed. The entire nervous system is more compact, and is completely separated from the skin. The foregut is larger than in the previous stage, and the walls of the masticatory stomach have become very much thickened. It is screened from the yolk by a membrane composed of large cells, which extend backward over the nerve cord. A double band of muscles (Figs. 168, 180, *g. m. a.*) passes upward from the anterior wall of the masticatory stomach and from the brain, to the body wall. These will be referred to the anterior gastric muscles.

The mesenteron (*mg.*) is very largely reduced in size and is filled with a granular coagulum, and, anteriorly next the head, with vesiculated and eroded remnants of yolk. The endoderm lines all but the anterior third of this cavity, extending farther forward on the dorsal wall. A few wandering cells are still present in the peripheral parts of the cavity next the advancing edge of the endoderm. Those elements, represented in Fig. 182, prove to be endoderm cells mechanically detached from the wall of the mesenteron. The primary lobes of the midgut ("liver") are larger but otherwise similar to those described in Stage x. The endoderm cells are greatly vesiculated, and the cell protoplasm has often a striated appearance.

The heart (Figs. 180, 186, *H.*) has undergone very considerable changes since the period represented by Figs. 164, 168. It is no longer dorso-ventrally flattened, but in transverse section it is triangular in appearance. One side of the triangle is toward the intestine and one apex next the body wall. Its suspension in the pericardium is very delicate. The ectoderm cells send down spindle-shaped processes (Fig. 186), the *Ectoderm pfeiler* of Reichenbach, and to these, mesodermal elements become attached. The cavity of the heart is imperfectly divided by lateral partitions into three longitudinal compartments. In Fig. 186 the partitions are imperfect and represented on each side by a single rudimentary muscle fiber. The walls and partitions of the heart are composed of delicate muscle fibers, which are distinctly striated. In the abdominal muscles, striations can also be made out.

Stage XII.—The first larva.

We now reach the stage with which this paper began, the first larva of *Alpheus saulcyi.* The histological structure of the zoëa in the species with a regular metamorphosis differs only in minor particulars from the larva already described. The organs are all very much smaller, and the cells are relatively larger and less compact. The mesenteron is about half filled with the unaltered and unabsorbed food yolk. Wandering cells are almost entirely absent, and the endodermal walls are nearly complete. The partition between the masticatory stomach and the midgut is absorbed and communication between them is established.

The anterior and median lateral divisions of the midgut are present, but the posterior lateral lobes are represented only by spaces not as yet walled in by endoderm. There is a slight dorsal median fold of endodermal cells. In the larva of the same species three days' old the posterior lateral lobes are formed, but are very small.

Stage XIII.—Alpheus ten days old.

In the first twenty-four hours the larva moults twice, but the histological changes in this period are not of a very extensive character. The organs which experience the most rapid growth are the gills (Pl. LIII, Fig. 195.). These have now acquired the folds or plates for increasing the respiratory surface, and are more efficient as breathing organs.

The fibrous tissue of the brain is relatively greater in bulk, and the tracts of fibers are more numerous and more complicated. The eye stalks are much shorter, and the optic ganglia and anterior parts of the brain are drawn closer together.

In a larva four days old (Pl. XXI, Fig. 3) the eyes are completely covered by the carapace. The ganglia of the eye stalks and brain are intimately fused together. The nervous system and all the tissues have undergone greater or less histological changes. These can be more conveniently considered in a still older larva.

The period of metamorphosis, strictly speaking, is passed in about twenty-four hours after the time of hatching. The structure of an Alpheus ten days old, which had spent its entire life in an aquarium will now be briefly considered. It is sexually immature and some of the organs, like the "liver" and green gland, are less complicated, but otherwise the structure is essentially that of the adult form.

When we compare the brain of the first larva with that of the ten days old and the adult fully grown form, we find the same parts present in all. In the last two the fibrous tissue is relatively much greater in bulk, and differentiation of the fibers and fibrous tracts has advanced much farther. The brain consists of the same fibrous masses surrounded with a thinner cortex of nerve and ganglion cells.

The anterior or optic enlargement is continuous on each side with the ganglia of the eye stalks. Its two halves are united by transverse fibers. The lateral enlargement is markedly kidney-shaped, and from its hilus there issues a complex system of fibers. A great part of these fibers issue from the ganglion cells inclosing the lateral ball, pass out in a bundle to the middle of the brain, and thence up to the optic ganglia, apparently without crossing. The fibrous substance of the lateral enlargement has a pyramidal structure—that is, its tissue is permeated with pyramidal blocks of a denser substance which stains faintly with carmine. The apices of these pyramids point toward the center of the ball. Below the lateral enlargement and nearer the middle line there is the antennular mass from which the auditory nerve issues. This is bilobed and has the same general relations as in the first larva (Pl. LV, Fig. 216, *lf.*). The antennal enlargement, which is closely connected with the latter, is now a much more conspicuous mass than in the earlier stage. From it issue the antennal nerve and the œsophageal commissures.

The alimentary tract has undergone very important changes, of which mention was made in Section I. What corresponds to the foregut of the larva comprises that portion of the tract from the mouth to the duct of the gastric glands. It is divisible into a straight and vertical portion, the œsophagus proper and a masticatory stomach. The latter consists of two parts, an anterior section continuous with the œsophagus, and probably corresponding with the gastric mill, and a pyloric portion or strainer. In transverse section the cardiac section appears circular and the walls are rather thin and slightly folded. As this passes into the pyloric division the floor of the tract rises into a broad-tongue-shaped process, which is surmounted by a particular strainer of hairs. This median fold is continuous throughout the pyloric division, where it narrows into a crest. The lateral walls, which are greatly thickened and studded with hairs, approach each other so that only a small lumen is left, through which the food is strained as it passes over the network of hairs. These two sections of the stomach correspond to portions of the tract marked *Ms.*, Fig. 196. They are of epiblastic origin, and in passing to the midgut the epithelium suddenly changes as it does in the larva.

The ducts of the three glands unite on each side and thus form two common ducts. The epithelia of the gastric cæca of the ducts and midgut are directly continuous and pass gradually into each other. They consist of a delicate layer of connective tissue which forms a capsular investment and the large columnar cells already described. In the "liver" many of these cells are in the process of active secretion, and as a result of this activity the lumen of the gland is filled with a coagulated liquid. The secreting cell at this period swells out to two or three times its former size and has the form of a distended bladder projecting into the cavity of the gland. The contents of the cell consist of a light granular fluid and when the cell breaks down this is discharged into the lumen of the gland.

Just how much of the wall of the alimentary tract behind the glandular ducts is of endodermic origin it is impossible to say, since from the first there is no sharp morphological boundary between the hindgut and mesenteron. But it is certain that only a very small portion of it can arise in this way, and that the endoderm of the larva goes mainly, if not exclusively, to form the lining of the gastric cæca.

The heart is very much compressed from above downward as in the adult. The walls of blood vessels consist of a single layer of cells which secrete a homogeneous limiting membrane. As in the early larva, the heart and pericardium are screened from the digestive tract and other organs by a horizontal membrane. The reproductive organs are still in the rudimentary condition already described.

V.—NOTES ON THE SEGMENTATION OF CRUSTACEA.*

Under this head I will add a few notes upon the segmentation of the egg of a number of Decapods, which have been studied chiefly for the sake of comparison with Alpheus.

Alpheus saulcyi and *A. heterochelis* are both typical examples of centrolecithal segmentation with the formation of yolk pyramids. They possess a massive food yolk and hatch as mysis-like

* The concluding sections of this memoir were written after the lapse of a long interval, during which time it was not possible to refer to my earlier manuscript. This will account for any unnecessary reiteration of facts, or for any inconsistencies in statement which I have failed to eliminate.

larvæ. On the other hand, the Bahaman variety of *Alpheus heterochelis* and *Alpheus minor* (from Beaufort, North Carolina) agree in having a relatively smaller yolk and in hatching as zœa-like forms. They differ, however, in their segmentation, the first species agreeing in this respect with *A. saulcyi*, while in *A. minor* yolk pyramids are generally absent and the segmentation is irregular. The yolk in *A. heterochelis* of Beaufort is about nine times as voluminous as that of the Bahaman *heterochelis*. The segmentation, however, has remained unaltered. The peculiarities which we find in the early stages of *A. minor* can not therefore be laid to the door of the yolk alone, but must be regarded as a comparatively recent modification of the yolk pyramid type. While the type of segmentation may be very persistent and uniform, it is subject to profound change, not only in closely allied species, but, as has been shown in a few instances, within the species itself.

In the Decapod egg we have, as a result of segmentation, a great central yolk-mass which is either undivided or imperfectly divided, and which completely fills and obliterates the segmentation cavity, and a surrounding layer of cells, the blastoderm. More fully stated the process is as follows: The segmentation nucleus divides first at a point near the center of the egg. The daughter cells separate widely, and a second division follows. With subsequent divisions the cells approach nearer the surface. The yolk may share in these early divisions but often does not, until eight or sixteen cells are formed (third or fourth segmentation stage). When there is no progressive segmentation of the yolk in the early phases, the yolk segments appear either gradually and on one side of the egg, or make their appearance simultaneously in relation to all the nuclei present. Segmentation is always rythmical. During one phase (period of "rest") the segments shrink away from the surface and flatten out in the usual way, while at the beginning of the period which follows (period of "activity") they swell and stand out prominently. The division of the yolk often appears total in surface views, while in reality it is not. The constrictions marking off the segments may be nearly superficial, or they may extend deep into the yolk. Cell division is usually indirect. The only exception to this rule which I have observed is *Alpheus minor* (see p. 397). With each division the protoplasm approaches nearer the surface of the egg, and the segments become more pyramidal in shape. These are the "yolk pyramids" which were first described in the crayfish by Rathke in 1829. The bases of the pyramids form the surface of the egg and their apices fuse in the central yolk mass. The nucleus, surrounded by a rayed body of protoplasm, lies near the base. By repeated division the pyramids become smaller; the cleavage planes of adjoining segments become less distinct and the protoplasm draws nearer and nearer the surface. Before, however, any of the protoplasm is flush with the surface, certain of the cells divide horizontally, that is delaminate, and one of the products of each division migrates into the yolk below. The surface of the egg is now covered with a single layer of small polygonal cells, and the pyramidal structure of the peripheral yolk has nearly disappeared. The greater part of the protoplasm of the egg is thus at the extreme outer ends of the reduced yolk pyramids, while the lesser body of it is represented by the migrating yolk cells.

The invagination stage soon follows, and the large numbers of cells which now become migratory (in Alpheus penetrating to all parts of the egg), joining the primary yolk cells, represent mesoblast and entoblast. The process above described will be found to apply, I believe, to the majority, if not to all Decapods. Differences in detail may be expected in the time of appearance of yolk segmentation and the degree to which this is carried. This account differs from that usually given in recognizing delamination, following close upon the latter phases of segmentation, or the origin of cells, from the blastosphere before the invagination appears. This regularly occurring in such typical forms as Alpheus and Homarus argues strongly for its presence in allied species where it has possibly been overlooked.

Stenopus hispidus.—I have described and figured the segmentation of Stenopus in a paper on the life history of this form. In one egg which I sectioned before the beginning of yolk segmentation, a single cell, probably the male pronucleus, is seen at the surface, while another cell, the female pronucleus, lies near the center. A single polar body was also present, just beneath the shell, near the first nucleus. I saw no evidence of yolk segmentation until the third phase of division was reached. The yolk then became constricted at the surface into eight blastomeres. The superficial furrows are quite deep during active periods, giving to the egg the appearance of total cleavage. This egg now resembles that of Penæus as figured by Haeckel, but in the latter form yolk segments

appear at an earlier phase. The cleavage of the yolk is wholly, or almost wholly, confined to the surface furrows, dividing planes rarely extending into the yolk below. My material was not adequate for determining whether invagination was preceded by delamination or not, but seems to render it highly probable that a delamination does not occur.

My observations on *Pontonia domestica*, *Palæmonetes vulgaris*, and *Hippa talpoides* are very fragmentary. In Pontonia I have one stage (Fig. 27) with three cells, one of which is dividing with no sign of yolk division, and another with sixteen nuclei and corresponding yolk pyramids. Here the conditions are precisely like those in *Alpheus saulcyi* at a similar stage, and probably the segmentation of the two is similiar. In *Palæmonetes* Faxon (17), relying wholly upon surface views, states that segmentation of the egg begins in two planes almost simultaneously. These planes are at right angles to each other and pass through the long and short axes of the egg. Whether this follows close upon the first division of the nucleus I have not determined. I have an egg with two nuclei near the center of the undivided yolk, and a stage with thirty-two yolk pyramids. This egg also agrees closely with that of *Alpheus saulcyi* at the same stage. The nuclei are not quite at the extreme surface of the yolk. In the next phase when sixty-four pyramids are present the protoplasm abuts on the surface (Fig. 24) of the egg. All the protoplasm is distributed to the yolk pyramids and no delamination has taken place.

With reference to Hippa I can only add the note that yolk pyramids normally occur, and in the 64-cell stage (Figs. 1, 4) the lines of cleavage between adjacent segments are very distinct and extend nearly to the center of the egg. At this stage all the protoplasm is apparently concentrated in these cells. Yolk pyramids similar in surface views to those of Hippa occur in *Callinectes hastatus*, *Platyonychus ocellatus*, and *Libinia canaliculata*.

Crangon vulgaris.—Kingsley (31) describes the segmentation of Crangon as follows:

> With the first segmentation the protoplasm begins to leave its central position and seek the surface of the egg; before the second division is completed it has reached the surface, leaving the yolk in the center. * * * After the second protoplasmic segmentation is effected the first segmentation furrows appear, the one following close upon the other. The first to appear corresponds in its direction to the first nuclear division; the second is at right angles to it. * * * In Crangon, so far as I have been able to see, amœboid cells reach the surface and take part in the formation of the blastoderm before the process of gastrulation begins. In that form no yolk pyramids occur.

Of cell division he says:

> In the process of cell division I have never seen any traces of karyokinesis; the division seems to be direct, and affects first the nucleus and next the protoplasm. * * * In fact I do not recall a single statement of karyokinesis being witnessed in decapod segmentation excepting in Astacus.

On Pl. I he gives a drawing (Fig. 3) of an egg with "about sixteen segmentation spheres." Fig. 4 of the same plate represents a section of the egg shown in Fig. 3 and has six nuclei, five of which are even with the surface, while one is near the center of the egg. The yolk spherules appear to be fused, owing possibly to the disturbing effect of the reagents employed. This central cell, according to Kingsley, represents a portion of the egg protoplasm which is belated in its passage to the surface, but it divides and gives rise to cells which eventually reach the surface at a certain point which marks the germinal area. Thus all the nuclei take part in the formation of the blastoderm, and the migration of the belated cells is completed before the "gastrula" invagination occurs. I have made no observations on the very earliest phases of segmentation of Crangon, but I have several eggs sectioned at the sixteen-cell stage, which ought therefore to correspond with Fig. 4 of Kingsley's paper, but, on the contrary, they show a somewhat different condition of things. There are just sixteen nuclei present, all of which are peripheral or nearly so, and each nucleus forms the center of a yolk pyramid, the cleavage planes of which are very marked and extend more than half way to the center of the egg. Fig. 15, Pl. XXVII, of the segmented egg of Alpheus, although belonging to a later phase, will fairly represent the condition of things which we find in Crangon. None of the nuclei are tangent to the surface, but between them and the surface there is still a considerable layer of yolk. Each is surrounded by a large mass of protoplasm, which stains lightly with hæmotoxylon, and has the characteristic rayed appearance. One of these nuclei is in the equatorial plate or metakinetic stage of division, and may be represented very nearly by Fig. 28, which shows a dividing cell in the egg of Alpheus at the same period. As already stated, the central yolk mass does not contain a single nucleus. The yolk is in the usual form of

large spherules on angular blocks, which are abundantly perforated with round lacunæ. Crangon agrees essentially at this stage with at least three other species, namely, with *Alpheus saulcyi*, *Pontonia domestica*, and *Stenopus hispidus*.

It is probable that Figs. 3 and 4 of Kingsley's paper do not correspond, the latter representing the older egg, that is, older than the sixteen-cell stage. In the segmenting eggs of Homarus there is a striking individual variation, which finds expression chiefly in the external characters of segmentation, but I have never observed this in any related forms, and can not say to what extent it occurs. Judging from analogy, I think it will be found that as a rule all the protoplasm in the egg of *Crangon vulgaris* reaches, or very nearly reaches, the surface, as in *Homarus* and *Alpheus saulcyi*, and that toward the close of the yolk-pyramid stage delamination occurs and some of it wanders back into the depths of the yolk. If this is true, the "belated" cell near the center of Fig. 4 of Kingsley's paper may represent some of the protoplasm which has taken this roundabout journey.

[While this memoir was in press a paper has appeared by W. F. R. Weldon, on "The Formation of the Germ-layers in Crangon vulgaris." (*Quart. Jour. Mic. Sci.*, Vol. XXXIII, pt. 3, March, 1892). He makes no mention of the budding of cells from the blastoderm before invagination, nor of the presence of migrating cells at a later period not derived from the invaginate cells or ventral plate, hence it is probable that in *Crangon* primary yolk cells do not occur. In this case the suggestion just offered does not let us out of the difficulty.] I have not succeeded in obtaining the segmenting eggs of Callianassa for comparison with the early stages of *Callianassa mediterranea*, described by Mereschkowski (40). It seems to me, however, that the diagrams in Mereschkowski's paper are misleading, and that the process of segmentation in Callianassa, instead of being peculiar as one might infer, is essentially typical. According to this observer's account the "blastoderm" arises without yolk segmentation. Nuclear division is at first central, and the resulting cells, sixteen in number, pass gradually to the surface and form a deep layer of protoplasm inclosing the yolk. This layer, at first raised into hillocks corresponding to the nuclei, finally segments into sixteen parts around the latter. These segments are formed simultaneously over the egg, but the yolk is not involved. The cells multiply rapidly and form a layer of tall prismatic elements, which gradually flatten out as division proceeds, into ordinary blastoderm cells.

If there is any analogy between this egg and that of related forms the broad "protoplasmic" layer is really the protoplasm plus the peripheral yolk. It would be remarkable in any case if a segmenting egg could acquire such a mass of protoplasm, not to speak of the suddenness with which the acquisition is made. That this layer, comprising more than one-half the contents of the egg, is largely yolk is indicated by the fact that the nuclei which occur in it are represented as surrounded by a protoplasmic reticulum as normally occurs. If this is true, the *prismatic cells* are *yolk pyramids*, and their line of separation from the central yolk is purely imaginary.

Ishikawa found, in his studies upon a Japanese prawn, *Atyephyra compressa* (27), that the egg underwent at first a total and regular segmentation. At the end of the fourth phase the yolk is centralized and the protoplasm surrounds it, and in the next stage, after thirty-two blastomeres have been formed, the central end of each separates off to form a yolk segment. The yolk segments, which fill the center of the egg and correspond to the common yolk mass with which the apices of the yolk pyramids blend in other Decapods, are of unequal size and contain nuclei which do not take part in the "blastoderm." These nuclei probably correspond to the delaminated cells of Homarus and Alpheus. In the latter they appear at the close of segmentation. It is quite probable that the time at which these cells are budded off may vary considerably in different species.

In *Eupagurus prideauxii* (39) Mayer found that the protoplasm segmented first in the center of the egg, as in other forms, until eight nuclei were present. When this stage is reached the yolk now segments not simultaneously into eight blastomeres, as in the case with the Isopod *Asellus aquaticus*, but according to its inherited primitive manner, first into two, then into four and eight spherules. Segmentation of the yolk is thus at first total, but after the fourth phase the spheres unite in a central yolk core as in other forms.

In *Alpheus saulcyi* I did not find any eggs which showed a progressive segmentation of the yolk between the stages represented in Figs. 9 and 10, and hence I infer, as already stated, that the segmentation of the yolk is there a simultaneous process for each of the sixteen segments

involved. This remark also applies to Stenopus, where eight blastomeres or yolk pyramids appear at the beginning of the third phase. In Homarus there is less uniformity in the appearance of the superficial segments, since the cells do not migrate to all parts of the surface at a uniform rate.

Lereboullet (36) described the early stages of the segmenting egg of the crayfish *Astacus fluviatilis* in 1862. His account, though somewhat vague and unsatisfactory owing to the technical difficulties under which he labored, is confirmed in essential particulars by a later observer, Skimkewitch (56), who has given a short description, without figures, of the process in the Russian crayfish *Astacus leptodactylus*. His account is briefly as follows: The cleavage nucleus with its protoplasm passes from the center to the surface of the egg and undergoes segmentation. The resulting nuclei, the exact number of which is not given, then diffuse over the surface of the egg and the yolk segments around them. The cleavage planes between adjacent pyramids, at first extend only half way to the center of the egg and never quite reach it. There remains at the close of the segmentation a small mass of undivided yolk ("*dotterkern*") lying in the center of the ovum.

According to these observations then, Astacus offers us an example of *centrolecithal* segmentation in the most exact sense of the term. It seems to me quite probable that this migration of the protoplasm may be only apparent, and that the segmentation may proceed much as it does in the lobster.

Brooks, in his memoir on *Lucifer* (8), gives an account of a segmentation which differs in some particulars from that of any macrouran which has been studied. The Lucifer egg undergoes a total and perfectly regular segmentation, and in the first stages may be compared with Eupagurus. In Lucifer, however, a segmentation cavity is formed, which can be clearly seen when sixteen spherules are present. At this time one pole of the egg becomes flattened, and one of the spherules in the area, which has become differentiated by the possession of food yolk, is gradually invaginated into the segmentation cavity. Meantime the invaginated cell divides; other changes ensue which lead to the infolding of more cells and the formation of a two-layered embryo, the "gastrula." Brooks thinks that the yolk-bearing cell represents a yolk pyramid, and that after a longitudinal division each half divides transversely or delaminates, and that the other two inner cells contain the yolk, while the outer products remain at the surface and form a part of the "blastoderm" (or endodermic invagination). This last point, however, was not settled. In Brooks's view the segmentation in Lucifer is a secondary modification of the yolk pyramid type, and this has been brought about "by the gradual reduction of the amount of food material and its restriction, at last, to a single one of the cells of the segmenting egg." He says that, while Lucifer is undoubtedly a very primitive Malacostracan, it can hardly be regarded as a primitive Crustacean; and since we meet with abundant examples of centrolecithal segmentation both above and below Lucifer, we can not regard the Lucifer egg as ancestral or as the unmodified descendant of an ancestral type of egg. "We must, therefore, believe that the egg of Lucifer has been simplified by the loss of the greater part of its food yolk."

It is to be regretted that Professor Brooks did not find material sufficiently abundant to warrant the sacrifice of some of the segmenting eggs for sections; for until this is done we can not be certain of the origin and relations of the mesoblast and entoblast in this extremely interesting species. A careful study of the subject both in Lucifer and Sergestes would form a very valuable and much needed contribution.*

It seems to me quite probable that we have in Lucifer a repetition of what occurs in Homarus and Alpheus, and that the yolk-bearing cell corresponds to the inwandering or delaminated cells, which occur in the lobster at the close of segmentation. In each case they arise by transverse division from the superficial cells of the blastophere. In each case, also, they appear just before invagination, and migrate into the segmentation cavity. The differences are that in the lobster, for instance, the segmentation cavity is already filled with yolk; the centripetal cells are numerous, and they do not necessarily come from that point on the surface which corresponds to the point of invagination or ingrowth. As to the comparative history of the two cells in the two cases little

* Since this was written Professor Brooks has announced in his report of the work of the marine laboratory of the Johns Hopkins University, that he has recently obtained the eggs of *Lucifer* in abundance at Jamaica, and is now engaged in studying its embryology.

can be said. Brooks thought that in Lucifer they represented the food yolk, although this was not settled. In Alpheus these cells are later joined by great numbers of wandering cells at the invagination period, and out of this common stock, so far as we can determine, both mesoblastic and entoblastic organs are developed. In Homarus, on the other hand, the invaginate cells unquestionably degenerate.

The eggs of *Scyllarus* and *Palinurus* have not been thoroughly studied, so far as I am aware. Dorhn (14), however, has figured the eggs of *Scyllarus arctus* in late stages of yolk segmentation, and in surface view they resemble, at this time, the ordinary Decapod type. We have as yet no knowledge of the segmentation of the Stomatopods.

The relations of the different varieties of segmentation which are met with among the Decapods, may be expressed by the following table:

- Segmentation of the Decapod egg.
  - I. Total: regular: segmentation cavity present.
    - (I). *Lucifer typus.*
  - II. Partial: centrolecithal (yolk pyramids): segmentation cavity filled with yolk.
    - Segmentation of yolk at first total, afterwards partial.
      - (1) *Palæmon.*
      - (2) *Eupagurus prideauii.*
      - (3) *Atyephyra compressa.*
    - (II). Segmentation of yolk.
      - Regular
        - (1) *Penæus.*
        - (2) *Crangon.*
        - (3) *Stenopus hispidus.*
        - (4) *Alpheus saulcyi.*
        - (5) *Pontonia domestica.*
        - (6) *Hippa talpoides.*
        - (7) *Palæmonetes vulgaris.*
        - (8) *Callianassa mediterranea.*
      - Irregular
        - (1) *Homarus americanus* (yolk segmentation at first irregular, but later regular or nearly so).
        - (2) *Alpheus minor.*

Of the Thoracostraca, the Schizopods undoubtedly depart widest from the common decapodal type of segmentation. Nusbaum (45) thus describes the process in *Mysis Chameleo:* The protoplasm—that is, the segmentation nucleus, with its protoplasmic body—retreats to a point at the surface of the egg. The nucleus then suffers division, and the protoplasm becomes differentiated into an outer striated zone containing a single nucleus, and an inner granular zone with one or more nuclei. The single external necleus divides and gives rise to a small blastodermic disk, formed of a single layer of hexagonal cells. From the internal nuclei and protoplasm a small number of nuclei are produced under the blastodermic disk. The free cells below the disk are the products (1) of the nuclei and formative protoplasm of the deeper layer, and (2) of the cells of the upper layer or blastodermic disk. While a solid accumulation of cells is thus being formed below the disk, the superficial cells gradually extend on all sides and inclose the egg. The thickened disk marks the *ventral* side of the embryo. It divides into a median, caudal, or *abdominal plate*, and two lateral plates, the *ventral bands.* Yolk cells which were not present up to this stage, now arise by migration from the abdominal plate.

The segmentation of the Schizopod is especially interesting, since it agrees so closely with that described in certain Isopods and Myriapods, and resembles also the segmentation of Arachnids.

Bobretyky's observations on *Oniscus* (5) need to be repeated, and especially in the early stages. According to this observer the earliest phase of segmentation was characterized by the anomalous withdrawal of the egg protoplasm to the surface, where it accumulated in a distinct body, and underwent segmentation. A disk of large columnar cells was thus formed, marking the ventral surface of the embryo. The cells spread with the thickening of the disk, until they inclose the entire egg. The superficial cells form ectoblast, the rest entoblast and mesoblast.

Morgan (41) has described a form of segmentation in *Pycnogonids* which resembles that of the Decapod. Here the invagination (which leads to the formation of the stomodæum) is preceded by the delamination of endoderm cells from the blastosphere, very much as in Alpheus, if we may regard the yolk cells as primitive endoderm.

In *Agelæna*, Locy (37) found the unsegmented egg to contain a central nucleus and protoplasm, united by a fine network to a peripheral protoplasmic layer, the blastema. The nucleus divides, and its products pass gradually into the blastema, which is used up in forming the blastoderm.

Bruce (10) speaking first of Bobretyky's work, thus describes the formation of the blastoderm in Lepidoptera:

> In the earliest stages he found four amœbiform cells in the yolk, situated in pairs at opposite ends of the egg. Later the blastoderm is formed by a multiplication of these cells; according to Bobretyky it is not formed simultaneously over the entire surface of the egg, but is laid down first at one or more points on the surface. This type of segmentation can not strictly be called entolecithal, inasmuch as the cells are not, in the earliest stages of segmentation, at the surface inclosing the yolk. All the primitive undifferentiated cells do not, according to Bobretyky, reach the surface to form the blastoderm, but some remain centrally located as yolk cells after the formation of the blastoderm. The earliest stages of segmentation observed in *Thyridopteryx* showed several amœbiform cells in the yolk in each cross section.

In *Thyridopteryx* the blastoderm is first formed in a given area on the surface, afterward completely inclosing the egg, but in this particular closely related insects seem to differ.

Heider's recent observations on *Hydrophilus* (24) show that numerous nuclei which originate from segmentation, do not reach the surface to enter into the "Keimhautblastem," but remain in the yolk as yolk cells.

The segmenting egg of *Julus terrestris* is described by Heathcote (19) as a syncytium. Segmentation is at first central, and the resulting nuclei are united by strands of protoplasm. Upon reaching the surface they spread themselves over it to form a blastoderm. The blastodermic cells are united to each other by strings of protoplasm, and to the cells of the yolk. The entire egg is thus pervaded by a network of protoplasm. The yolk cells are regarded as entoblast, and give rise to the "keel" or thickened blastodermic plate. This stage, characterized by a thickened blastodermic disk, keel, or cumulus, probably corresponds to a similar stage which is met with in Schizopods, Isopods, Myriapods, to the primitive cumulus in Arachnids and the ventral plate which suffers invagination in some insects. Possibly it corresponds also to the invagination plus the thickened ventral plate of Alpheus and Homarus.

Possibly we have in Astacus and Homarus an approach to the mesoblastic type of segmentation, such as is found in Mysis. This would be reached in Astacus if the protoplasm (which according Skimkewitch passes at once to the surface) should in the course of division build up a disk, instead of diffusing itself over the egg. A similar result would be achieved in Homarus if the belated cells should not reach the surface at all, and if those which are first to appear should not diffuse over the egg, but segment to form a thickened plate.

Balfour says, in speaking of forms like Penæus:

> It is probable that *not* all the nuclei which result from the division of the first segmentation nucleus become concerned in the formation of the superficial blastoderm, but that some remain in the interior of the ovum to become the nuclei of the yolk spheres.—(*Comp. Embryology*, Vol. I, p. 113.)

This, I think, is an error, and that what is true of a number of forms, as Alpheus, Crangon, Homarus, probably expresses the rule for the Decapods, that all the egg protoplasm enters into the peripheral cell layer. Exceptions to the rule may, however, occur.

The use of the term *centrolecithal* to express the relations of the protoplasm and the yolk in the egg of Arthropods is not beyond criticism, but the strict application of a single term is clearly impossible. The ground of any objection is sufficiently covered by Balfour, in emphasizing the fact that *it is the centrolecithal condition which is eventually attained.* He says:

> As might be anticipated on the analogy of the types already described, the concentration of the food yolk at the centre of the ovum does not always take place before segmentation, but is sometimes deferred till even the later stages of this process.—(*Comp. Embryology*, Vol. I, p. 110.)

In most cases the protoplasmic segmentation is at first *central*, or, as Kingsley points out, ectolecithal, and then, after passing through the intermediate stage, it is finally centrolecithal.

The question as to whether the products of the segmentation nucleus before the yolk is involved, are to be regarded as independent *cells* was raised by Balfour, who, in reference to Bobretyky's work on the embryology of insects, says:

> He regards the nuclei surrounded by protoplasm, which are produced by the primitive segmentation nucleus, as so many distinct cells. These cells are supposed to move about freely in the yolk, which acts as a kind of intercel-

lular medium. This view does not commend itself to me. It is opposed to my own observations on similar nuclei in the Spiders. It does not fit in with our knowledge of the nature of the ovum, and can not be reconciled with the segmentation of such types as Spiders, or even Eupagurus, with which the segmentation in insects is undoubtedly closely related.—(*Comp. Embryology*, Vol. I, p. 119.)

This discussion seems to have arisen from a confusion of the morphological and physiological significance of the cell. The segmentation of the nucleus and its surrounding protoplasm is plainly the only important phenomenon, and the segmentatior of the yolk is not merely a secondary process, but in many cases a wholly unnecessary one, as we see in the early phases of many Decapods. In these cases the individuality of the yolk pyramid is temporarily sacrificed or subordinated to that of the true cell, which is surrounded by unsegmented yolk. Later, when the yolk has become divided, the yolk segment or pyramid is gradually reduced until we get the superficial, embryonic cell, with more or less definite boundaries. All the elements of the egg, whether superficial or amœboid, are clearly to be regarded as cells in a fundamental, physiological sense, as shown by the part which they play in the development of the embryo.

SECONDARY SEGMENTATION OF THE YOLK.

There are traces of a *secondary segmentation* of the yolk in Alpheus during the second, third, and fourth stages; that is, from the period of invagination to the outlining of the primary appendages. The yolk spheres arrange themselves in spherical clusters or balls, so characteristic of the early development of nearly all the Arthropods. The yolk ball contains at least one yolk nucleus with perinuclear protoplasm and corresponds to a yolk pyramid, being a *cell* in the same sense as the latter. Various phases of this secondary segmentation may be seen by glancing over Pls. XXX–XXXV In one egg, which I sectioned just prior to invagination (Fig. 46), there appears a segmentation of the yolk around the central nuclei.

Bobretzky attributes a morphological value to the secondary segmentation of the yolk in Arthropods, supposing it to be connected with the spreading and final establishment of the entoblast. The secondary yolk pyramids or giant endoderm cells, which form the lining of the midgut of the embryo crayfish, he compared with the *Dotterballen* of Oniscus and Palæmon. In Palæmon the food yolk breaks up into round or polygonal pieces soon after the blastoderm is formed, while in Oniscus certain cells pass into the yolk from the keel or germinal eminence and gorge themselves with the yolk substance until they form large balls, which represent the endoderm (Darmdrüsenzellen). It is stated, however, by Nusbaum (44) that a part of the endoderm of Oniscus which gives rise to the gastric gland arises from primitive mesoblast, and in insects the endoderm is formed independently of the yolk cells. The history of the yolk cells and of the wandering cells will be discussed in another section.

VI.—CELL DEGENERATION.

The rapid and often extensive breaking up and final disappearance of embryonic cells in the course of Arthropod development is a very remarkable phenomenon, and strange to say, it has almost escaped attention up to the present time among the Decapod Crustacea. A study of this subject in Alpheus, Astacus, and Homarus has convinced me that the peculiar bodies described as secondary mesoderm cells in the crayfish (54) correspond to the degenerating, sporelike particles which characterize similar stages in the development of both Alpheus and Homarus.

In some early notes on the development of Alpheus I called these nuclear fragments "spores" (22), but the term is inappropriate if we are dealing with cells in the process of dissolution, as is undoubtedly the case. The anomalous "secondary cells," which have been a sort of outstanding puzzle to embryologists, receive, in my opinion, a more reasonable explanation on the ground that they represent degenerating elements. This view is supported by a comparative study of embryonic growth in other Arthropods.

Alpheus.—Degenerating cells are present in *Alpheus saulcyi* in considerable numbers when the nauplius appendages are budding and increase for a short time beyond this period. They continue in greater or less quantity until six to eight pairs of postoral appendages are formed, when they disappear from the embryo almost completely. They vary in size from small refringent particles to spherical masses as large as ordinary nuclei, or even larger. Many nuclei, instead of having the normal appearance, in which the chromatin has the form of a coil or a reticulum with stellate

nodules in its meshes, begin to show retrogressive tendencies. They sometimes appear swollen out to an unusual size, and their chromatin is aggregated into a single large ball, which may become vesicular and strongly refractive. The chromatin ball is sometimes of large size, central in position, and stained intensely, suggesting strongly the nucleus of a blood cell, or it may stain so faintly as to be hardly recognizable. Again, it may be eccentric and attended by one or more smaller balls, or the nuclear body may be filled with numerous coarse grains. These bodies then recall yeast cells in process of producing ascospores. As in the yeast cell, the wall of the nuclear body seems in many cases to break down and thus set free into the yolk the naked, spore-like masses of degenerating chromatin.

In Figs. 21 and 32 (Pls. XXVII, XXIX), taken from the egg-nauplius embryo, we see various stages of this process. Around the stomodæum, and within or near the pockets of the antennæ and mandibles, there are large numbers of these pseudo-spores. Some are small chromatin balls (s), which combine actively with hæmotoxylon, while others stain feebly or are quite unaffected by the dye, and resemble straw-colored particles of vesiculated and altered food yolk. Below and to either side of the stomodæum there is a granular residue (Fig. 118, A. Y. S.), composed of yolk and nuclear matter in various stages of chemical degeneration.

The ordinary nucleus in the resting condition is generally characterized by the presence of balls, nodules, or granules of various sizes, which represent chromatin constituents of the nucleus. Under high powers these usually appear as stellate masses suspended in the nuclear reticulum. A number of representative nuclei are shown in Fig. 18. They are all drawn to scale and are taken from the egg-nauplius series under review. It is so plain that it is hardly necessary to state it, that the nuclear fragments in these bodies, *e*, *f*, or *h* for instance, correspond to similar fragments which occur free in the yolk. The larger nodule in the nucleus *f* resembles figure *b*, except that the latter is surrounded by an outer light zone. This zone is often very large and not as sharply defined as in the drawing. Again, figure *c* resembles figure *b*, except that the outer light zone is larger in *c* and the chromatin or stainable residue has nearly disappeared. I regard the bodies *b* and *c* as masses of degenerating chromatin which have escaped from a disrupted nucleus or cell. In *c* the retrogressive changes are furthest advanced. Finally, when the chromatin or stainable matter has been completely disorganized, there is left a vesiculated mass which stains very feebly or not at all, and resembles yolk (Figs. 102, 107, A. Y. S.). Nearly every drawing of the egg-nauplius stage shows one or more bodies resembling *b* in Fig. 18 (see Fig. 21, s, s^2, and Fig. 32, s^1). In many cases the outer light zone is cloudy, as already stated, and the element resembles a spherule of yolk with a ball of chromatin imprisoned in it. These bodies bear a certain resemblance to blood cells, but this resemblance is probably transitory, and after a careful study of a great many stages I can find no direct evidence that they are ever reorganized into new tissue. The blood cell of the adult is shown in Fig. 19 and that of an embryo in Fig. 35. In each case it consists of a deeply staining granular nucleus and a clear cell body. The nucleus corresponds to the apparently naked yolk nucleus (Fig. 35, Mes.; Fig. 18, etc.) and the cell body to the perinuclear protoplasm, which is present, though often of small quantity, in the wandering cells. As we have already shown, it is probable that the blood cell (Fig. 35, B. C.) is derived directly from the wandering cell (Mes.), and that the characteristic appearance of the cell protoplasm is a rapid acquisition.

Degenerating nuclei may be seen by glancing over the plates (Pls. XXXVII–XXXIX and XLI–XLIV), but it is unnecessary to refer to these in detail.

The dorsal plate or dorsal organ (?) furnishes a most striking instance of the degeneration of cells (Pl. XXIX, Fig. 36; Pl. XLVI, Fig. 153). Its cells seem to originate from the ectoblast, with accessions possibly from the wandering cells. After the slight ingrowth, which takes place in the middle of the plate, many of the cells pass into the depths of the egg and break up into meteoric clouds of small deeply staining particles.

To sum up the previous remarks which relate to the appearance of these bodies in Alpheus, degenerating cells are first seen in Stage IV, and in the following egg-nauplius stage they are abundant. In Stage VII (Pl. XLIV, Fig. 131) they are still present, and in Stage VIII there is a fresh irruption of degenerating products into the yolk, arising from the centripetal cells of the dorsal plate. At a slightly later period they have almost wholly disappeared. Even as late as in the tenth stage a few chromatin granules can be seen in the region of the dorsal plate.

CELL DEGENERATION AND AMITOSIS IN ALPHEUS MINOR.

In the segmentation of *Alpheus minor* there are numerous cases which illustrate the fragmentation and apparent degeneration of nuclei. A nuclear body sometimes seems to be breaking down and discharging a large number of sporelike balls or grains of chromatin (Fig. 26, Pl. XXVIII, *S. C.*). This probably represents an element in process of dissolution. If this be true, the clear area is similar to the plasmalike mass shown in Fig. 13, in which the nuclear bodies have disappeared from view. Clear areas are sometimes seen containing only minute particles of nearly dissolved chromatin. The large swollen bodies, like those shown in Fig. 23, each with a single, often minute, ball of chromatin, certainly remind us of somewhat analogous structures which can be seen at a later stage in the crayfish.

The egg sectioned in Fig. 12, Pl. XXVI, contains eight large nuclear nests or shells. The nuclear masses are seen to be very irregular in size, and in some instances the nuclei are unquestionably breaking down. In other cases the egg contains a smaller number of large, very irregular masses of nuclear material, consisting of a fine network, with chromatin granules in suspension. These nuclear masses sometimes appear to be constricting into two parts. The swarm of small nuclei, like that shown in Fig. 13, I interpret, as already stated, as arising by a kind of budding of the large nuclear mass and the subsequent constricting off of the buds.

It is very interesting to find that in this case, possibly the only case of amitotic cell division in the segmentation of the ovum yet recorded, the indirect division of the nuclei is followed to some extent by a degeneration of these bodies. This lends some weight to the view that indirect division is connected with the senescence of nuclei.*

The nuclei of the large endoderm cells lining the mesenteron in the crayfish appear to divide directly, and in this case the process is again followed by dissolution. In may, however, prove that we have here a case of multiple karyokinesis, similar to that which I have recently observed in the superficial cells of the lobster embryo, where nests containing from four to sixteen closely packed nuclei are very characteristic of certain early stages.

CELL DEGENERATION IN ASTACUS AND HOMARUS.

Homarus americanus.—I find certain bodies in the lobster essentially similar to those which characterize the Alpheus embryo. If a longitudinal section of the egg nauplius of Homarus be compared with Fig. 125, which represents a similar section of a similar stage of *Alpheus saulcyi*, we find not a few chromatin balls, but a meteoric swarm of granulated bodies and naked chromatin grains coextensive with the embryo, and reaching a considerable distance into the yolk amid the scattered mesodermic cells, but perhaps most abundant, as in Alpheus, in the neighborhood of the stomodæum. A long nebulous train of yolk spherules and granules extends forward a considerable distance in front of the mouth, and is especially marked in front of the optic disks. The labrum and the folds of the appendages which contain yolk abound in these peculiar granulated bodies. In less number they occur in connection with the endoderm cells, which have at this stage extended through a greater portion of the egg and form a series of irregular sacs filled with yolk. These yolk masses, with their surrounding sheet or advancing column of cells, correspond to the endoderm sac of the crayfish. In the latter the peculiar cell bodies also occur.

If one now examines very thin sections under high powers, we find that the granules and the granulated bodies correspond in general to the structures we have found in Alpheus. The chromatin grains appear sometimes as naked masses in the yolk; sometimes they possess a distinct protoplasmic body. The degenerating chromatin stains either very intensely or faintly and is often vesiculated; that is, it appears as a hollow shell. Under favorable conditions it is easy to demonstrate the fact that these bodies surround particles of yolk, and occasionally they have a crescentic shape, when it can be clearly seen that they are enwrapping a yolk spherule. This vitellophilus

* While this memoir was in press a paper was received on *Amitosis in the Embryonal Envelopes of the Scorpion*, by H. P. Johnson, (Bulletin of the Museum of Comparative Zoölogy, Vol. XXII, No. 3). Only two instances of direct cell division in the embryo of Arthropods are recorded: that found by Carnoy in the ventral plate of *Hydrophilus piceus* and the case which Wheeler has described for the blastoderm of *Blatta germanica*. Mr. Johnson finds that degeneration does not always follow upon indirect cell division, as in the case of amitosis in the testicular cells of certain Isopods.

characteristic is certainly not so apparent in Alpheus, yet I believe that in this form it is present in some stages, though in a less marked degree.

Astacus (?)—I have studied several critical stages in the development of the crayfish, critical at least so far as the appearance of degenerative products is concerned, with an eye to comparison with Alpheus and Homarus.* The youngest set of embryos corresponds nearly to Reichenbach's stage E, but differs from it in some details. Rudiments of five pairs of appendages are present, the two maxillæ being seen between the mandibles and the thoracic-abdominal process. None of the appendages, however, are folded. The mouth is seen on a line between the first and second pair of antennæ.

The bodies which Reichenbach calls "secondary mesoderm" occur in abundance in or near the wall of the endoderm sac next the embryo. They also abound in the yolk under the ectoderm, and are most numerous in the area extending from the optic invaginations to the mouth or slightly behind it. In this respect they recall the distribution of similar bodies in Alpheus and Homarus.

I wish to call attention to the fact that at this stage none of my sections show a cavity in the endoderm sac, as is represented by Reichenbach (compare Taf. VIII, 54), and the endodermal yolk segments or pyramids do not always possess completed walls. To what extent this appearance is normal, and to what extent due to the action of reagents, I can not at present say. These eggs were treated with hot water and corrosive sublimate. The endodermal nucleus is surrounded by a thin layer of protoplasm, which works its way amid the yolk so as to practically surround a pyramidal mass. This strongly recalls the serpentine manner in which the endoderm cells creep through the yolk in Homarus. Whether these cells in Astacus are simply migrating in a column or sheet, spreading gradually towards the periphery of the egg, as in the lobster, cannot be decided from the material at my command, but it is a point of considerable interest in its morphological bearings. The endodermal cells probably multiply indirectly, but I saw no nuclear figures in my sections, and they appear also to divide directly, independently of the yolk pyramids as Reichenbach has described, giving rise to the chromatin balls and granulated elements (compare Fig. 20) but, as pointed out above, this appearance may be very deceitful. This process is most marked in the endodermic area noticed above, underlying the anterior half of the embryo. Here we see great numbers of the bodies of varying size, both within and without the domain of the endoderm cells. They closely resemble the vitellophagous elements which I have described for the lobster, and possibly they attack the yolk in a similar way. Where they are thickest the yolk is comminuted and shows traces of profound chemical change. In the midst of the altered yolk one can discover very faint outlines of vesicular bodies which exhibit but slight reaction to the stain. These I regard as degenerated cells.

The next stage of Astacus which I have studied corresponds nearly to Reichenbach's stage G. Eight pairs of appendages are present, and there are rudiments of a ninth pair. The first and second maxillæ appear as distinct buds, while the third pair of maxillipeds is represented by a proliferating cell area only. The extremity of the abdomen is not bifid.

In the central part of the endodermal sac there is a coagulable fluid which comes in close relation with the posterior end of the embryo. The endodermal cells laterally have quite or nearly reached the ectoderm, while dorsally they fall a little short of the surface. The yolk within the confines of the endoderm has an irregular, pyramidal, or radial cleavage. Centrally the yolk blends with the serum-like fluid, in which occasional granules or balls of chromatin may be found. Small spherical elements (like those represented in Fig. 18, *a*, *b*, *c*, or *k*, *k*,[1] Fig. 20), containing a single chromatin ball or several balls, occur not only in the yolk underneath the ectoderm and in the vicinity of the endodermal nuclei, *but also in the central yolk of the endoderm sac*, at various levels below the endodermal nuclei. This is a point of some interest in connection with the fate of these bodies. They wander not only peripherally but centrally. Rarely we meet one which is three or four times the average size, having a small chromatin spherule in its center. In later stages they are present in far less numbers.

---

* For the opportunity of studying the crayfish development at this time I am indebted to the kindness of my friend, Dr. William Patten, who sent me a number of important stages collected at Milwaukee.

Reichenbach thus summarizes his observations on the "sekundäre Mesodermzellen:"

Die fraglichen Elemente sind als Zellen zu deuten, deren Kerne nicht immer die Beschaffenheit gewöhnlicher Zellkerne haben, dieselbe aber früher oder später erlangen (Fig. 20, m, m², Plate XXVII). Sie nehmen ihren Ursprung innerhalb derjenigen Entodermzellen, welche die ventrale Wand des Urdarmsäckchens zusammensetzen durch eine näher zu erforschende Art endogener Zellbidung, bei welcher die in der Mehrzahl in den Elementen des Entoderms vorhandenen Kerne eine wichtige Rolle zu spielen scheinen. In den dem Stadium D vorangehenden Entwicklungsperioden hat jede Entodermzelle meist nur einen Kern; dies trifft auch noch zum Theil für Stadium D zu. Bald vermehren sich aber die Entodermkerne ganz erheblich und endlich beginnen die sekundären Mesodermzellen aufzutreten. Wenn eine grössere Zahl der sekundären Mesodermzellen in den Entodermelementen liegen, so scheint das Kernmaterial verbraucht zu sein. Es wandern nun aller Wahrscheinlichkeit nach diese Zellen, deren Kerne anscheinend noch in der Metamorphose sich befinden, aus dem Entoderm aus und begeben sich unter die Embryonalanlage. Die betreffenden Contouren des Entoderms lassen oft noch Spuren dieser Wanderung erkennen. Ob sie wirklich aktiv auswandern oder auch ausgestossen werden, ist nicht festzustellen gewesen. Sie begeben sich nun unter die übrigen Mesodermzellen und sind bald nicht mehr von ihnen zu unterscheiden. Aus diesem Grund führte ich für sie den Namen "sekundäre Mesodermzellen" ein, während die älteren Urmesodermzellen als primäre bezeichnet werden. Da die letzteren die Tendenz zeigen, zu kompakteren Massen zu verwachsen, so darf man wohl vermuten, dass die sekundären Mesodermzellen die Blutzellen liefern werden (54, p. 36).

It is interesting to notice that in Alpheus, Astacus, and Homarus degenerating cells appear in greatest force at about the egg-nauplius stage, and from that time on their numbers begin to wane. In Astacus, Reichenbach first noticed the "sekundäre Mesodermzellen" in stage D (that is, when the optic disks, the thoracic-abdominal plate, and the mandibles are outlined), which nearly corresponds to Stage IV of Alpheus. In stage D the bodies in question are most abundant under the optic disks (Kopflappen) and in the region of the upper lip, but become more generally distributed in the egg-nauplius.

According to Reichenbach, "gastrulation" takes place after the optic disks are formed, but unfortunately his paper is incomplete at a very important period, namely, from the late yolk-pyramid stage of segmentation, when the protoplasm is at the surface, to the time when an embryonic disk or plate (Entodermhügel or Entodermscheibe) has been formed. It is impossible, therefore, to follow the history of the so-called "white yolk elements." He says of the latter:

Sie bestehen aus protoplasmatischer, feinkörniger Substanz und enthalten vacuolenartige Einschlüsse, die ihnen ein schaumiges Aussehen geben; ich habe sie als weisse Dotterelemente bezeichnet. Sie liegen entweder dicht unter dem Blastoderm oder im Centrum des kugligen Eies und verschwinden sehr bald (Op. cit., p. 7).

According to my view these bodies correspond to the vesiculated elements (*m*, Fig. 20), and both represent cells in process of dissolution. If Figs. 18 and 20 are compared (the latter being a copy of Reichenbach's Fig. 67) we will find a striking correspondence between these peculiar cell products in both Astacus and Alpheus, a correspondence which is even more marked when the comparison is made with the lobster.

Reichenbach emphasizes the statement that naked balls of nuclear material never occur free in the yolk outside the endodermal sac. In this yolk they always have a "cell body" as K, Fig. 20. It is an easy matter, however, to distinguish naked masses of chromatin, minute spherules, or smaller granules in the yolk of both the lobster and Alpheus.

My studies of the lobster are not yet completed, but from the observations which have already been made I draw the following conclusions: In Alpheus, the lobster, and the crayfish similar bodies make their appearance at nearly similar times and play a similar rôle. They are derived from all three layers of the germ, and in *Alpheus minor* degenerative products make their appearance in the segmentation stages. They tend to break up and ingest the yolk and to produce in it a chemical change, possibly in order that it may be more easily assimilated by the other embryonic cells. Having performed this task they degenerate; they are converted into a substance resembling yolk and function as nutrition. That any play a formative rôle, giving rise to blood cells for instance, as Reichenbach supposes, there is no direct evidence. The vitellophagous function seems to be in abeyance in Alpheus, but in all cases the yolk is comminuted and chemically changed in the neighborhood of these bodies. Nusbaum (45), following Morin, believes that the "white yolk elements" arise from the segmentation nucleus and migrate to the surface of the egg; that they give rise to the "secondary mesoderm," which are taken up along with the yolk by the amœboid, endodermal cells. This is reversing the account, and, in so far as the origin of the "secondary mesoderm" is concerned, it is not supported, so far as I am aware, by a single observation.

Ishikawa (27) finds in Atyephyra after the close of the invagination stage, certain protoplasmic elements under the ectoblast, which he thinks may correspond with the "white yolk elements" just referred to, and he also identifies "secondary mesoderm cells," but does not trace their origin or function. They are "small granules," easily stained by logwood solution, and some are of considerable size and have a clear cell outline. "These are mostly aggregated in the cephalic region between the involutions of the ectoderm cells, but are also found in all places." In time of appearance and in their position, he says they seem to correspond to the "secondary mesoderm cells" of Astacus. This short notice with his figures leaves little doubt that these bodies are similar to those just described in Alpheus and Homarus. Fig. 62 of his paper represents a longitudinal median section of the egg-nauplius, and may be compared with the same stage of Alpheus (Figs. 104, 105), with respect to the general character and appearance of the degenerating cells.

I have noticed similar nuclear fragments in the egg-nauplius of a crab (Fig. 113, Pl. XL), and Lebedinski (34) has described "secondary mesoderm" in the embryo of the Mediterranean sea crab, *Eriphia spinifrons*. According to this observer they are found in all stages from the "gastrula" on, to the egg-nauplius; they are derived from ectoderm, and probably give rise to blood cells. In the stage with one pair of maxillipeds these elements are in active proliferation:

> Man findet, die Zellen desselben bieten verschiedene Momente und Zustände des Zerfallens dar; dieses Zerfallen der Zellen steht in genauen Zusammenhänge mit der Entstehung der Blutkörper.

He further says:

> Ueber die Bildung des Blutes kann ich nichts bestimmtes mittheilen. Im Stadium des ersten Paars kieferfusschen sind die ersten Blutkörperchen vorhanden, welche zum ersten Mal im Bereiche des Herzens vorkommen, wo sich auch am frühesten das sekundäre Mesoderm rückzubilden beginnt.

From these quotations it appears that the "secondary mesoderm" shows signs of degeneration, and its conversion into blood cells is an unverified inference. It seems more probable that the structures in question correspond with similar bodies already noticed in Alpheus, Homarus, and other Decapods, and that in all cases they have to do primarily with the dissolution and not with the construction of cells.

Wheeler (67) in his careful paper on the development of the Cockroach and Potato beetle (*Blatta germanica* and *Doryphora decemlineata*) describes an interesting case of the decomposition of nuclei, which bears a close analogy to what takes place in Alpheus and probably also in Astacus. In Doryphora two masses of endoderm are found, one under the stomodæum the other under the caudal plate. At both these places numerous cells which originate in the endoderm pass into the adjacent yolk and disappear. The process of dissolution is described as follows:

> The karyochylema becomes vacuolated, probably with substances absorbed from without, to judge of the larger size of some of these nuclei, while the chromatin ceases to present the threadlike coil and becomes compacted into irregular masses between the vacuoles. Finally the vacuoles fuse and the masses of chromatin, formally numerous, agglomerate to form one or two large irregular masses which usually apply themselves to the wall of the clearly vesicular nucleus * * * In the last stages seen the masses of chromatin lie between the yolk bodies, all other portions of the nucleus having disappeared. They still take the deep red stain, but finally become comminuted and disappear in the intervitelline protoplasm.

The vesiculated elements recall similar bodies which appear in Reichenbach's plates. Thus the element *t*, Fig. 88 of Wheeler's paper, where the chromatin is applied to the walls of the nucleus, strikingly resembles nucleus *i*, Fig. 20 (see this paper), where the chromatin is similarly disposed around the wall of a vacuole.

Bruce (10) figures certain yolk cells undergoing what he considered to be endogenous cell division in an advanced embryo of a spider, and compared it with the endogenous cell division which Reichenbach describes as taking place in the endoderm cells of Astacus.

The disintegration which has been attributed to the leucocytes of the mammalian blood affords an interesting comparison with the phenomena which have been described for the Arthropod embryo. Howell's careful observations (25) support the view that the multinucleated leucocytes are disintegrating cells. "The leucoblasts enter the lymph stream, and eventually reach the blood as unicellular leucocytes." Here they undergo changes, acquire amœboid movements, while the nuclei elongate, become constricted, and finally fragmented. "The multinuclear stage * * * is probably followed by a complete dissolution of the cell." Howell adopts the highly reasonable

view that the nuclear fragments persist for a while in the circulation as the blood plates, and considers it probable that the latter take some part in forming the paraglobulin of the blood. If the blood plate is then a degenerate body, it may be compared to the spore-like masses of chromatin, which are discharged from the disrupted cells in the lobster or crayfish embryo.

VII.—THE ORIGIN AND HISTORY OF WANDERING CELLS IN ALPHEUS.

The wandering cells in Alpheus have a triple origin, from the blastosphere, from the invagination, and from the thoracic-abdominal plate. Those which arise from the blastula at the close of segmentation are, perhaps, the representatives of a primitive endoderm. Following the invagination, a thick pad of cells is formed, the ventral or thoracic-abdominal plate. From this plate a general migration of cells occurs on all sides into the yolk (Pls. XXXII–XXXV). While there is a great tendency to migrate to parts underlying the embryonic area, the cells nevertheless wander to all parts of the egg, even to those most remote from the embryo. The first of these wandering bodies which originate from the blastosphere have been called "primary yolk cells." The latter classes may be called "wandering cells." Since these classes can not be distinguished after a certain period, I refer to all cells which move about in the yolk and have no direct connection with the thoracic-abdominal plate, and the parts of the embryo in front of it as *wandering cells*. I have been somewhat at a loss to find a suitable term for these bodies, since there are obvious objections to the use of "yolk cells" or "yolk nucleus." Where these terms have been employed in the present paper, they must be understood to refer to the wandering cells which have been defined above. The term "embryonic nuclei" is used for convenience merely to discriminate the remaining nuclei of the egg from those of the wandering cells.

The object immediately in view is to determine the fate of these wandering cells, to ascertain what formative rôle they play while the mesoderm, and more particularly the endoderm, are being differentiated into definite cell layers. In the following account, cells which have parted all connection with the thoracic-abdominal plate and have entered the yolk are enumerated as wandering cells. In an earlier part of this paper I gave an account of the origin and supposed fate of the wandering cells, the general conclusion being that in the early stages (Stages III–V) they pass from the yolk to the embryo and to the extra-embryonic parts* of the egg, and contribute to both mesoblastic and entoblastic structures.

A number of friends to whom I showed my sections objected to this interpretation on the ground that these wandering cells could be regarded with equal probability as originating, in some measure at least, in the opposite way, that is, as budding from superficial cells not concerned with the thoracic-abdominal plate, and migrating into the yolk. A careful study of successive stages would not support this idea, but the objection could not be satisfactorily answered, and neither view could be readily proved. I therefore undertook a renewed and more precise study of the wandering cells in Alpheus, and I think that their fate has been definitely settled.

The number of wandering cells which occur in the yolk, and the number of "embryonic cells" (that is, all the other cells of the egg) have been enumerated in five different stages, including seven different embryos, from the period of delamination at the close of primary yolk segmentation to the early egg-nauplius condition (Stages II–V.) This covers the most important period so far as the wandering cells are concerned. The rate of increase of both wandering cells and embryonic cells has also been determined for the successive stages, and the data are given in Table I.

* There is a certain convenience in thus referring to the embryo proper and to the less differentiated regions, while it is understood that all the cells constitute the embryo.

TABLE I.—*Showing the number of nuclei in yolk, and the number of other "embryonic nuclei," and the relative increase and decrease in these bodies from the close of yolk-segmentation to the egg-nauplius period.*

Stage.	Number of nuclei in yolk.	Increase in number of nuclei in yolk.	Decrease in number of nuclei in yolk.	Number of "embryonic nuclei."	Increase in number of "embryonic nuclei."	Total number of nuclei of egg.	Total increase in nuclei of egg.	Increase per cent of nuclei in yolk.	Decrease per cent of nuclei in yolk.	Increase per cent of "embryonic nuclei."
II. Delamination (Figs. 38–45, 46, Pl. XXX)	*34	.....	.....	284	.....	318	.....	.....	.....	.....
II. Invagination (*a*) Figs. 49–55, Pl. XXXI	*37	3	.....	421	137	458	140	8	.....	32½
II. Invagination (*b*) Figs. 49–55, Pl. XXXI	*37	3	.....	430	146	467	149	8	.....	34
III. Optic disks (Pls. XXXII, XXXIII)	199	162	.....	†736	306	935	468	81	.....	42
IV. First antennæ, mandibles (Pls. XXXIV, XXXV)	240	41	.....	†915	179	1,155	220	17	.....	20
V. Early egg-nauplius (*a*) Figs. 34, Pl. XXIX; 101–105, 107, Pl. XXXIX	199	.....	41	†2,989	2,074	3,188	2,033	.....	21	69
V. Early egg-nauplius (*b*) Figs. 34, Pl. XXIX; 101–105, 107, Pl. XXXIX	128	.....	112	†2,230	1,315	2,358	1,203	.....	87½	59

* Primary yolk cells.

† Number obtained by method described below.

The distribution of the wandering cells and of the embryonic nuclei is also illustrated by a series of curves, constructed in the following manner: Each vertical row of the smaller squares corresponds to a section of the ovum (Sections Nos. 1, 2, 3, etc.), while each square in this row represents a single nucleus. The number of nuclei in a section is shown by the number on the line where the curve makes a bend or intersects the middle of the lower side of a square (nuclei Nos. 1, 2, 3, etc.). Thus where the descending line of the curve in Fig. 5 stops in section No. 2, making an angle in the fifth vertical square, counting from the upper base line, this implies that in the second section of the egg, corresponding to this vertical area, there were five nuclei which did not appear in the following or preceding section.

The number of nuclei were determined in the following way: Camera-lucida drawings were made of every section of a given series on thin paper and each nucleus was marked. Then, by superimposing upon each drawing the drawing of the section immediately following, every nucleus new to that section could be determined in the early stages with absolute certainty. The number of primary yolk cells and wandering cells were thus counted in all stages. In the older embryos (see numbers marked with dagger in Table I, Stage III–V) where this method became impracticable with reference to the total number of embryonic nuclei, their number was estimated in a different manner. The nuclei appearing in each section were counted and the total number of nuclear sections was thus obtained for the whole series. Then the percentage which the actual number of nuclei in the egg bore to the total number which appear in sections could be determined approximately by the method described above applied to a number of lateral sections, that is, by actual count of nuclei in a favorable part of the series. The percentage which the actual number of wandering cells bears to the total number appearing in section could be exactly determined and compared with the former estimated percentage. The percentage which involved the wandering cells was in the average of all stages a trifle the smaller, showing that the yolk cells were, on the average, a little larger than the other embryonic nuclei. In Stage II before invagination the superficial nuclei are the larger, while after invagination the difference is at first very slight indeed. In Stages III and IV the wandering cells are markedly the largest in the egg, while in Stage V they either equal or fall slightly below the size of the other embryonic nuclei.

This method presupposes a perfect series of sections of uniform thickness. These conditions were approximately fulfilled. The egg ($\frac{1}{2}^{mm}$, or $\frac{1}{50}$ inch in diameter) was cut, on the average, into 57 sections, each section being $\frac{1}{114}^{mm}$ in thickness. The size of the egg, neither too small nor too large, rendered this species (called throughout this paper the Bahaman variety of *Alpheus heterochelis*) most favorable for study so far as technical difficulties were involved.

STAGE II.—*Close of yolk segmentation—Formation of yolk cells, followed by invagination.*—A surface view of this egg is given in Fig. 47, Pl. XXX. The curve (Fig. 5 of text) shows that the blastodermic cells are distributed very uniformly. In other words the embryonic area is not as yet marked off. The distribution of the primary yolk nuclei, of which there are exactly thirty-four, is shown in the constructed figure (Fig. 3), which represents the egg as it would appear if the yolk were transparent and the nuclei opaque. The distribution of these nuclei through the egg is given more completely by the curve (Fig. 4). The only questions which need detain us in this stage are, how do the primary yolk cells arise and from what part of the surface do they come? Karyokinetic figures, which abound among the surface nuclei, ought to furnish an immediate answer to the first question. In this egg no less than sixteen nuclei are met in various phases of division, fifteen of these belonging to the superficies and one to the central portion of the yolk. Clusters of two and rarely of three nuclei also occur at the surface, showing that cell division is active. In every case the cleavage is radial or perpendicular to the surface, and in no instance have I seen an unambiguous case of delamination (v. Pl. XXX). It is possible, however,

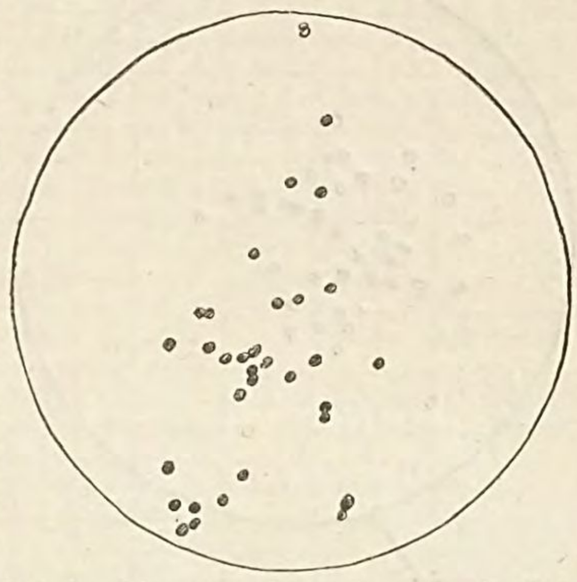


FIG. 3.—Diagram of egg in delamination stage, constructed from serial sections, showing all the primary yolk cells. For details, see Table I, Stage II (Delamination).

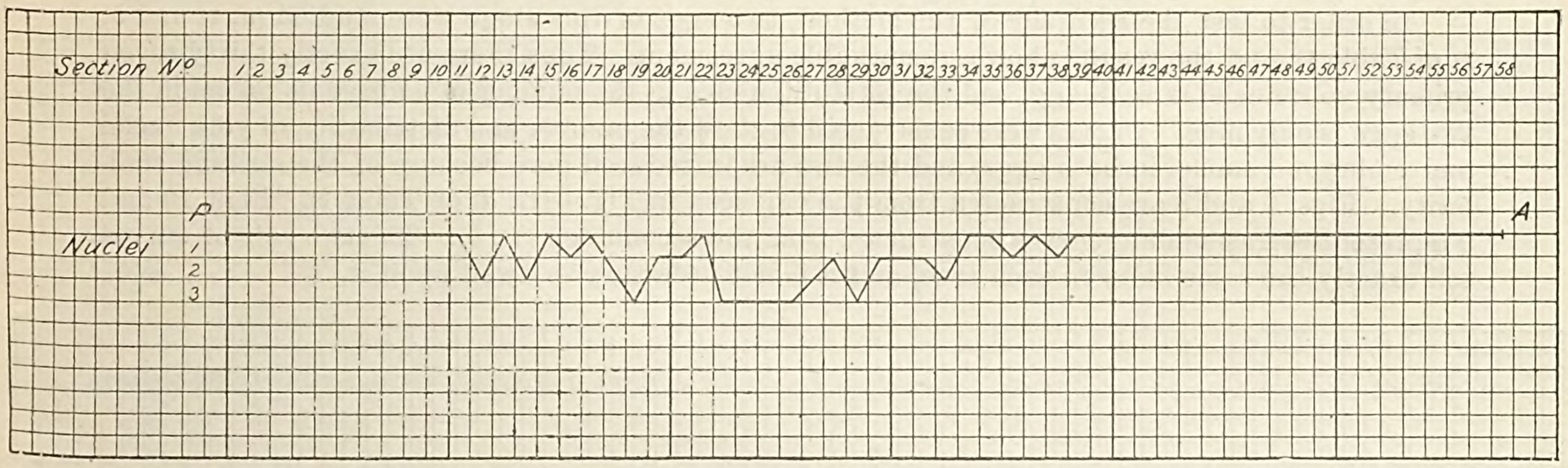


FIG. 4.—Curve constructed from serial sections, showing the distribution of the primary yolk nuclei in the egg represented by Fig. 3. For further details, compare Table I, Stage II (Delamination). *A*=Anterior; *P*=Posterior.

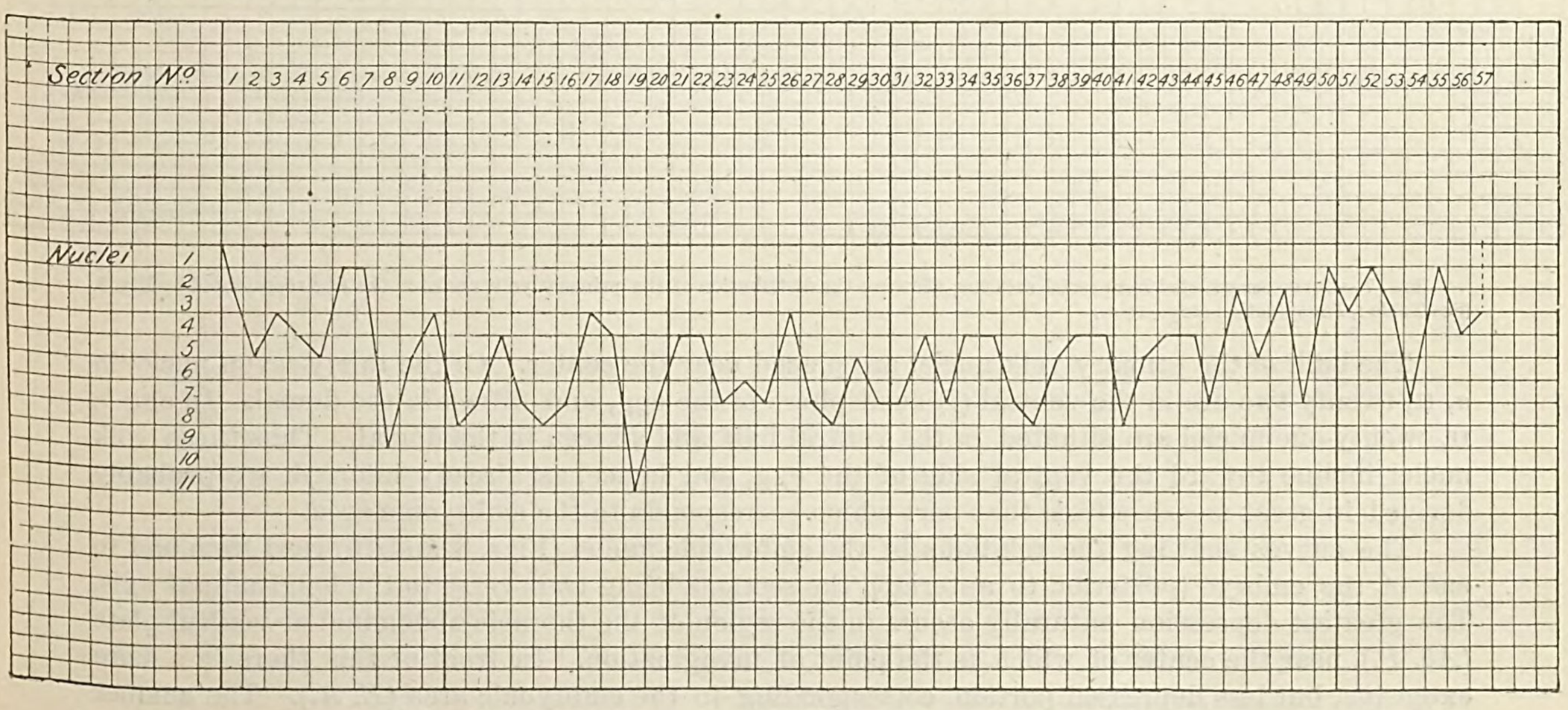


FIG. 5.—Curve showing the distribution of nuclei at the surface (that is, nuclei of the embryonic cells, exclusive of primary yolk cells) of the egg represented by Figs. 3 and 4. For details, see Table I, Stage II (Delamination).

that the primary yolk cells are formed in this way rather than by emigration, and that my failure to detect the actual process is due to the fact that I did not section exactly the right stage, the egg shown in Figs. 38–45 being a trifle too old. In Homarus the primary yolk cells arise by delamination, as I have already shown in a preliminary paper in the development of this form (23, Fig. 5).

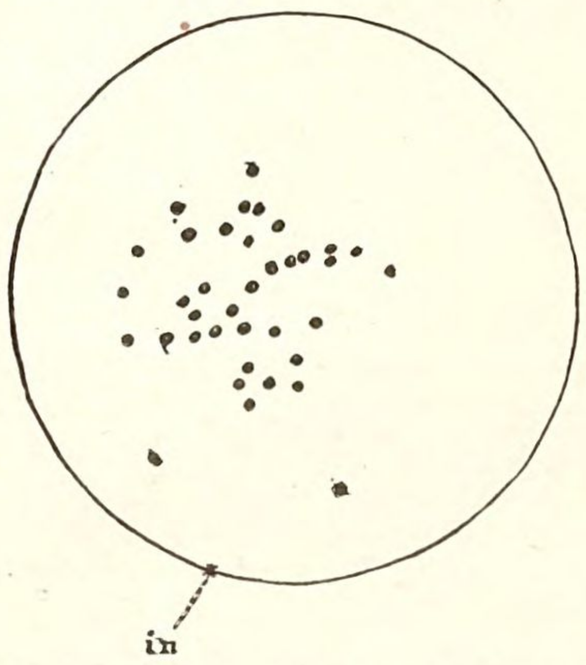


FIG. 6. — Diagram of egg in invagination stage, constructed from serial sections, to show all the primary yolk nuclei present. For details of this egg, see Table I (II, *a*), Invagination. *In* = point of invagination, nearly in the plane of the paper.

Sections of this stage show conclusively that the primary yolk nuclei do not come from any one point on the surface, but that the majority of them may come from a restricted area of the egg. In Fig. 3 about two-thirds of the nuclei present are confined to the lower (ventral ?) surface of the egg. They are in various degrees of progress from the surface toward the central parts, which the majority have already reached.

The formation of primary yolk cells is followed by the invagination and ingrowth of certain cells at the surface. The histology of the embryo at this phase is given in Pl. XXXI, and Fig. 6 (of text) is constructed from the entire series of sections to show all the primary yolk nuclei present. The plane of the paper (supposing the drawing to represent a sphere) nearly passes through the point of invagination (*in.*).

In order to test the accuracy of the method, two eggs of this stage were studied (*a*, II and *b*, II of Table I), and the results show a remarkable agreement. Thus there are exactly thirty-seven primary yolk nuclei in each egg, and the total difference in the number of embryonic nuclei in the two eggs is only nine. Curves were constructed to show the number and distribution of yolk nuclei and embryonic nuclei in both eggs, and the two are introduced here because of the striking similarity. Figs. 7 and 8 are constructed from the egg seen in Fig. 6 (II, *a*, of Table I). Figs. 10 and 9 represent corresponding curves constructed from the second egg (II, *b*). The two sets of curves tell exactly the same story in each case, and it is not necessary to dwell upon it.

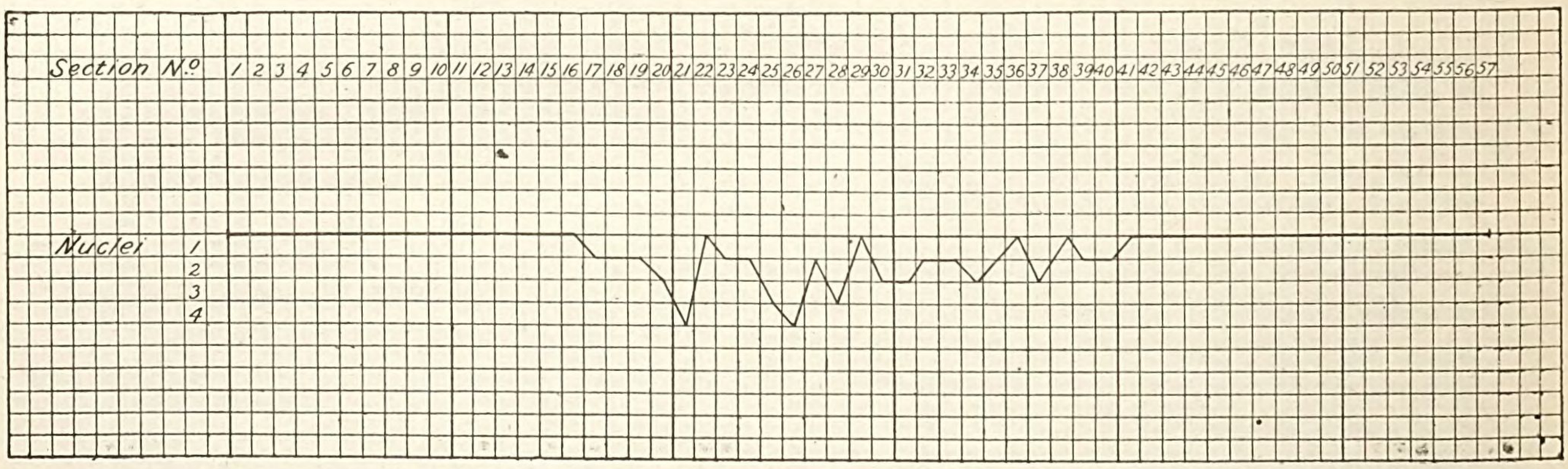


FIG. 7.—Curve constructed from serial sections, showing the distribution of the primary yolk nuclei in the egg represented by Fig. 6. (See Table I, Invagination stage, II, *a*.)

The bulk of the primary yolk nuclei are placed near the center. Of the thirty-seven nuclei in *a*, II, twenty-two are in the ventral (?) hemisphere of the egg, and fifteen in the dorsal. In egg *b*, II, twenty-one nuclei are situated in the ventral half and sixteen in the dorsal. Thus these yolk nuclei incline toward the ventral side of the egg, and hence, as already inferred, are probably derived in great measure from that part which corresponds to the embryonic area.

The curves showing the relations of the embryonic nuclei (Figs. 8 and 10) read from end to end of the embryo (posterior to anterior), the sections being transverse to the longitudinal axis. The greatest depression naturally occurs in the region of the thoracic-abdominal or ventral plate (*Ab. P.*), near the center of which is the point of invagination. In front of this there is a more extensive, but less depressed portion, corresponding to the embryonic area (*E. A.*). The number of cells entering into the ventral plate at this time are shown in Table II.

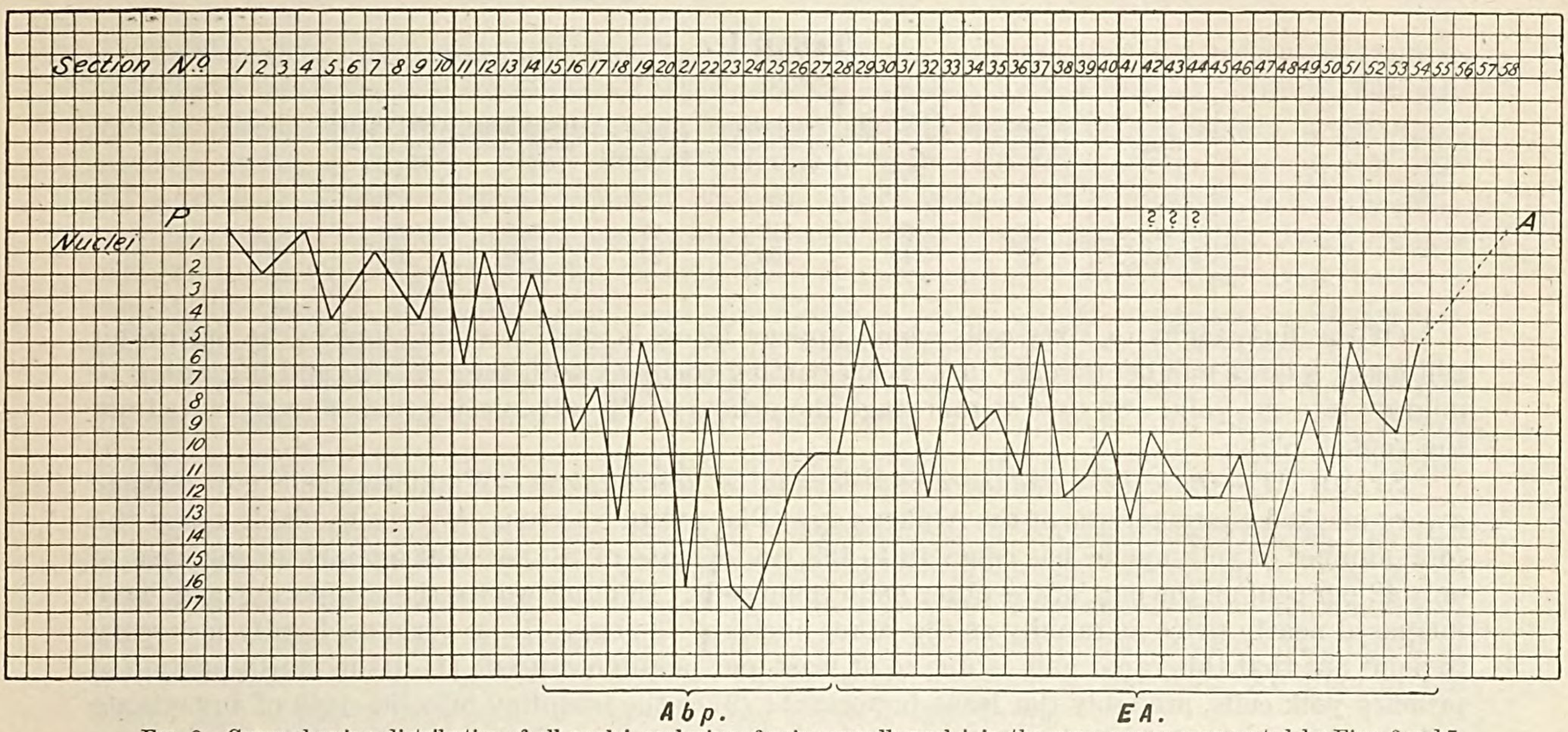


FIG. 8.—Curve showing distribution of all nuclei, exclusive of primary yolk nuclei, in the same egg as represented by Figs. 6 and 7. (See Table I, Invagination stage, II, *a*.) *A*, Anterior; *P*, Posterior; *Abp*, Ventral plate; *EA*, Embryonic area.

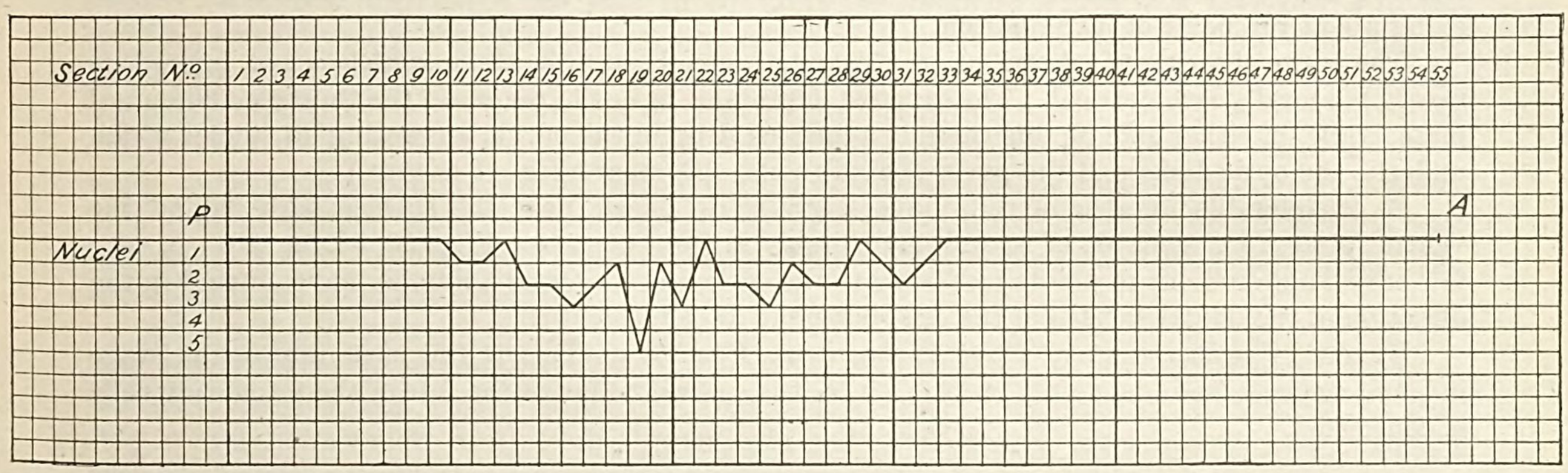


FIG. 9.—Curve showing the distribution of the primary yolk nuclei in the invagination stage, egg No. II, *b*, Table I. (Compare with Fig. 7.)

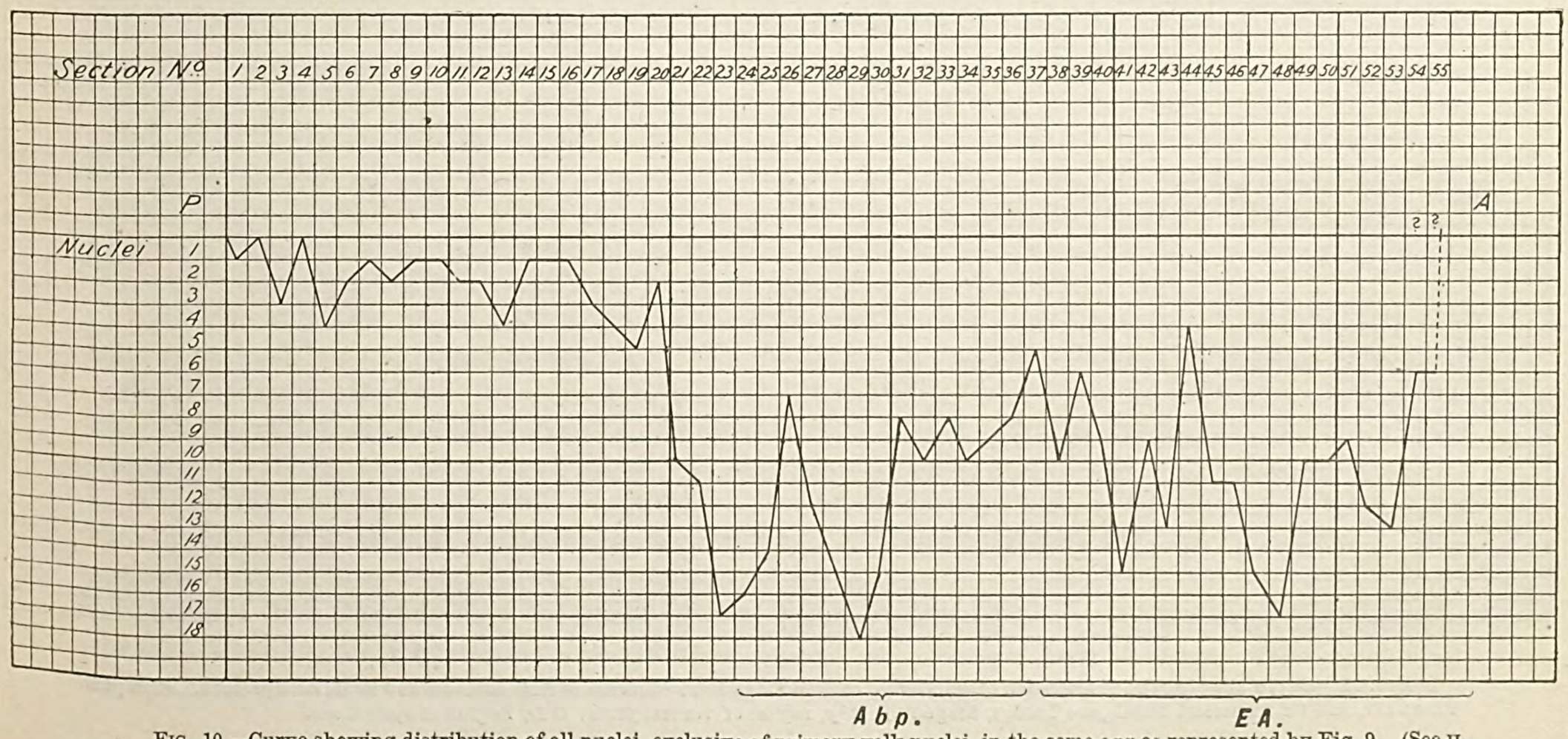


FIG. 10.—Curve showing distribution of all nuclei, exclusive of primary yolk nuclei, in the same egg as represented by Fig. 9. (See II, *b*, Table I, and compare with Fig. 8.) *A*, Anterior; *P*, Posterior; *Abp*, Ventral plate; *EA*, Embryonic area.

TABLE II.

Stage.	Nuclei at surface of Ab. P.	Nuclei in Ab. P., below surface.	Total number of nuclei in Ab. P.	Primary yolk nuclei.	Remaining embryonic nuclei.	Total number of nuclei of egg.
a, II.....	56	60	116	37	305	458
b, II.....	52	48	100	37	330	467

Of the forty-eight to sixty cells which appear below in surface at this time in the ingrowing cell mass, a large number (twenty in *b*, II) are parting company with their fellows and beginning to migrate into the yolk. So that at this stage the primary yolk cells receive their first recruits from the ventral plate.

STAGE III.—*Optic disks and thoracic-abdominal or ventral plate.*—Wandering cells now become a very marked characteristic of the Alpheus egg (Pls. XXXII, XXXIII). We see by Table I that the total number of yolk nuclei has come up to 199, an increase of 81 per cent against an increase of only 42 per cent on the part of the other embryonic cells. In other words, the wandering cells have increased nearly twice as rapidly as the other nuclei of the egg. It is, perhaps, hardly necessary to point out that this rapid gain is due to at least four possible causes: (1) to the multiplication of primary yolk cells, probably the least important; (2) to the irruption into the yolk of invaginate cells, or cells derived from these, the most important source; and (3) to the multiplication of the latter in the yolk itself; and (4) to migration from the ventral plate, which is formed by a thickening about the point of invagination.

The curve showing the distribution of wandering cells at this stage (which is not figured) is nearly bilaterally symmetrical. The greatest depression is in the region of the thoracic-abdominal plate, while on either side of this there is a marked drop in the curve, answering to nuclei which underlie the optic disks and the parts behind them. (Compare Fig. 11 of text.)

A considerable number of cells have migrated to points near the surface both behind the ventral plate, to either side of it, and immediately in front of it (see Figs. 56, 58, 59, 60). A very few have wandered out to points just beneath the optic disks. Quite a number have started in the direction of the dorsal surface of the egg, but none have reached it.

STAGE IV.—*Rudiments of First Antennæ and Mandibles.*—This is the most interesting stage in some respects (see Pls. XXXIV, XXXV), since it is critical so far as the fate of the wandering cells is concerned.

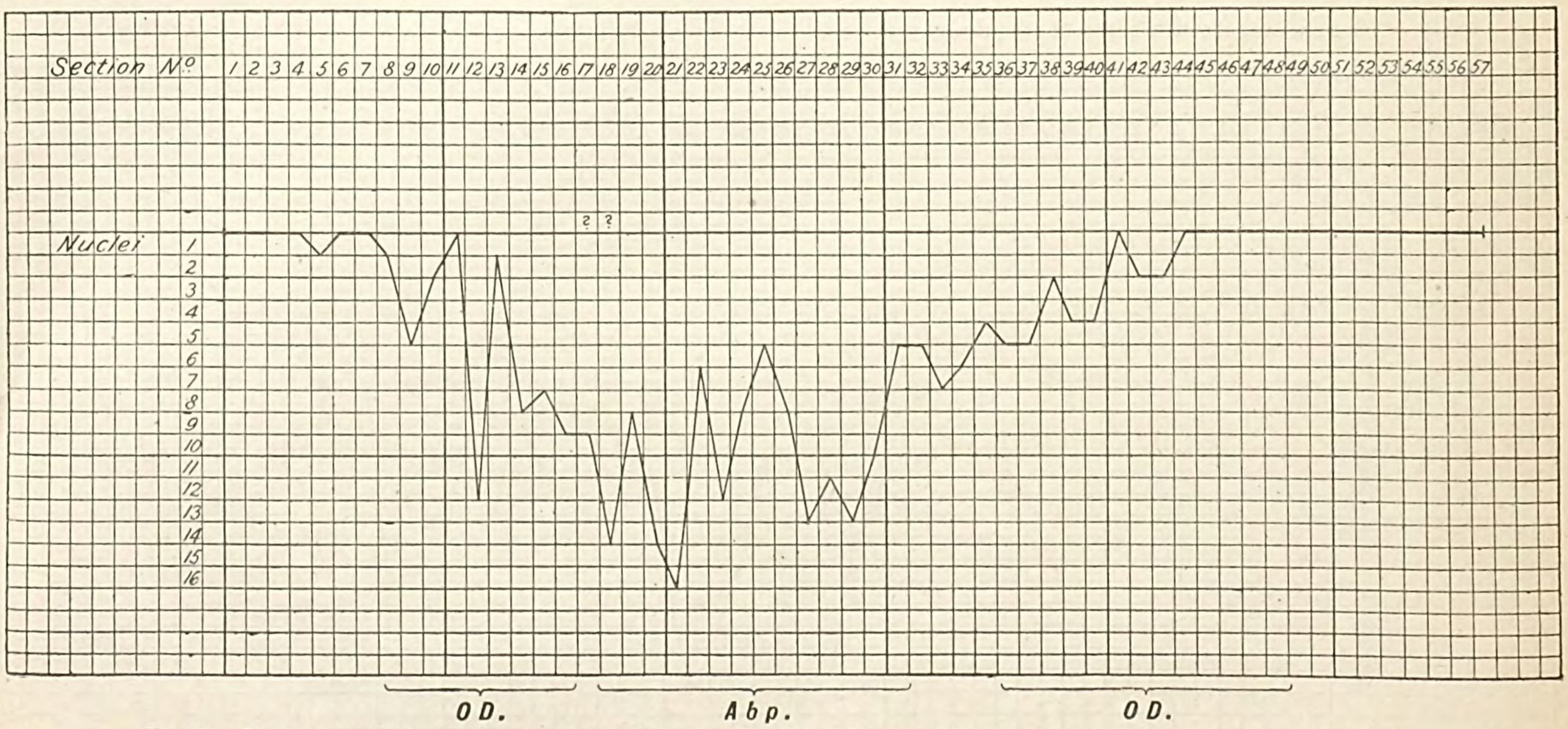


FIG. 11.—Curve showing the distribution of wandering cells in Stage IV, rudiments of first antennæ and mandibles present. (Compare Pl. XXXIV, and for numerical details, see Table I, Stage IV.) *Abp*, region of ventral plate; *O D*, Region of optic discs.

Table I shows the remarkable fact that the percentage of increase of wandering cells, which in Stage III was twice as great as that of other embryonic nuclei, has now dropped until it is actually less than the latter. This means that the wandering cells are multiplying less rapidly or that their numbers are being depleted. The relative increase of yolk nuclei from Stage II to III, and from Stage III to IV, namely, 81 per cent and 17 per cent (showing a marked falling off), is not specially significant, since these numbers depend largely upon the age of the embryo or time which elapses between successive stages. But this element does not enter into the relation which exists between the relative increase of wandering and embryonic cells in the same egg, expressed by 81 per cent and 41 per cent, respectively, in Stage III and by 17 per cent and 20 per cent in Stage IV.

The curve constructed from Stage IV (Fig. 11) shows the wandering cells much more widely diffused through the egg than at any earlier period. The thoracic-abdominal plate is no longer sharply marked off from adjacent parts, and a considerable number of nuclei underlie the optic disks.

In this egg there are thirty-seven nuclei in various phases of karyokinesis (Figs. 70, 75); two belong to the yolk, three to the deeper cells of the thoracic-abdominal plate, and the rest to the surface cells of the embryo. In the optic-disk region a very few cells appear to be delaminating; the rest are cases of radial division. Cell disintegration has not yet become a disturbing factor in the enumeration of cells. There are but two nuclei in the egg, one in the yolk, the other in the deeper part of the ventral plate, which show any traces of dissolution.

The above facts lead to the conclusion that the wandering cells are being rapidly depleted at this time, that they leave the yolk in considerable numbers and attach themselves to the growing embryo and to the extra-embryonic surface of the egg. They thus warrant our interpretation of a cell like *yc*, Fig. 70, or *yc*^{1}, Fig. 71, as a migrant from the yolk. While the wandering cells are being rapidly depleted, it does not of course follow that they never receive *any* recruits from *any* part of the egg without the limits of the ventral plate, and it requires no very elaborate calculation to show that wandering cells are making early contributions to the mesoblast, but the study of individual sections and the facts brought out in Table I, prove beyond a doubt that the only cells which enter the yolk, up to this time, arise from one of the three sources already named, the blastoderm, the invagination, and the ventral plate.

STAGE V.—*Egg-Nauplius.*—The early egg-nauplius stage is represented by two individuals, one (V. *a*, Table I) cut in transverse and the other (V. *b*) in longitudinal vertical planes. Respecting the wandering cells we now notice: (1) that their numbers have markedly decreased; (2) that they are far more widely and evenly distributed; and (3) that many are close upon or in contact with the embryo or with the general surface of the egg.

In egg V, *b* (Table I) the number of yolk cells is only one hundred and twenty-eight, considerably less than are present in Stage III, a decrease of 87 per cent, while in the other egg the decrease is 21 per cent. On the other hand, the rate of increase of embryonic nuclei is greater than at any previous stage, 59 per cent in one egg and 69 per cent in the other. That this is not explained by a large interval of time existing between Stages IV and V is shown by the fact that during the period (Stage IV and Stage V, *b*, Table I) the total number of nuclei of the egg has scarcely more than doubled, while the percentage of increase of embryonic nuclei has more than trebled. Between Stages II, *a*, and III, on the other hand, the number of nuclei has nearly doubled, while the percentage of increase of embryonic nuclei has risen from 32½ to only 42.

How is this very rapid increase in embryonic nuclei and coördinate decrease in wandering cells explained in the egg-nauplius stage? The conclusion reached in Stage IV applies here also, with a certain restriction. The problem is now not a simple one, since perturbations caused by the disintegration of nuclei appear to some extent in this stage. The diminution in the number of wandering cells is now due to two causes, to cell disintegration and to the gradual subtraction of cells from the yolk by emigration. Disintegration of cells occurs both in the yolk and in parts of the embryo. It is perhaps most marked near the line of contact of the yolk with the embryo. Yet the embryonic cells are meantime making a rapid net gain.

We are thus warranted in our conclusion that the wandering cells, which spread far and wide through the egg, play a formative rôle in development, to a large extent at least. This conclusion is rendered certain by the changes which ensue between Stages II and IV, already noticed. The

percentage of increase of wandering cells between Stages II and III is double that of the embryonic cells. Between Stages III and IV the increase per cent of wandering cells is less than that of the embryonic cells, and up to this time cell disintegration is ruled out as a disturbing factor.

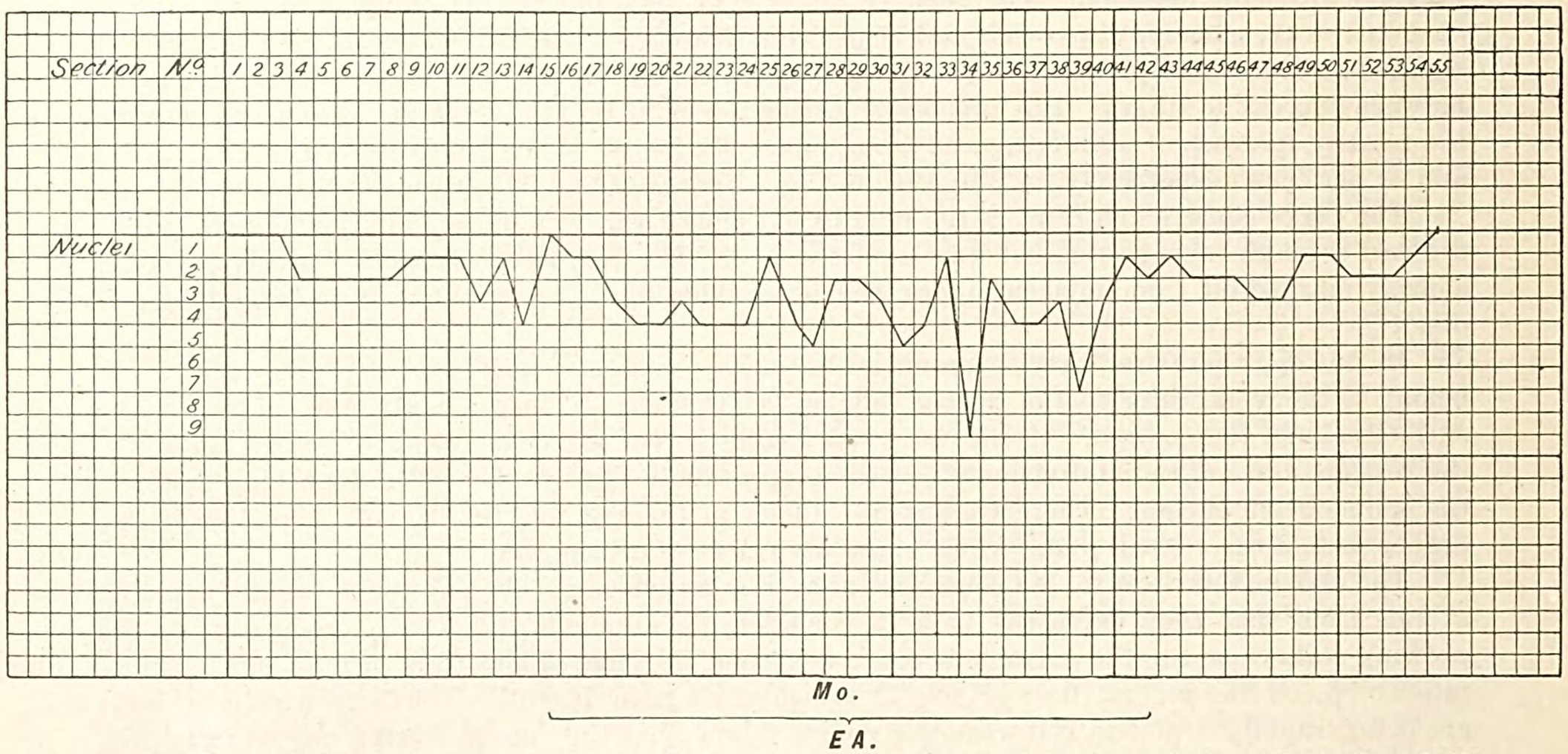


FIG. 12.—Curve showing distribution of wandering cells in Stage V (Early egg-nauplius). (Compare Fig. 11, and for details, see Table I, Stage, II *b*.) *E A*, Embryonic area; *Mo*, Mouth.

The second fact which was pointed out as characteristic of this stage, the distribution of the yolk nuclei commensurate with that of the yolk itself, also points to the conclusion already reached. This is well shown by two curves (Figs. 12, 13). In curve 13, which is constructed from a series

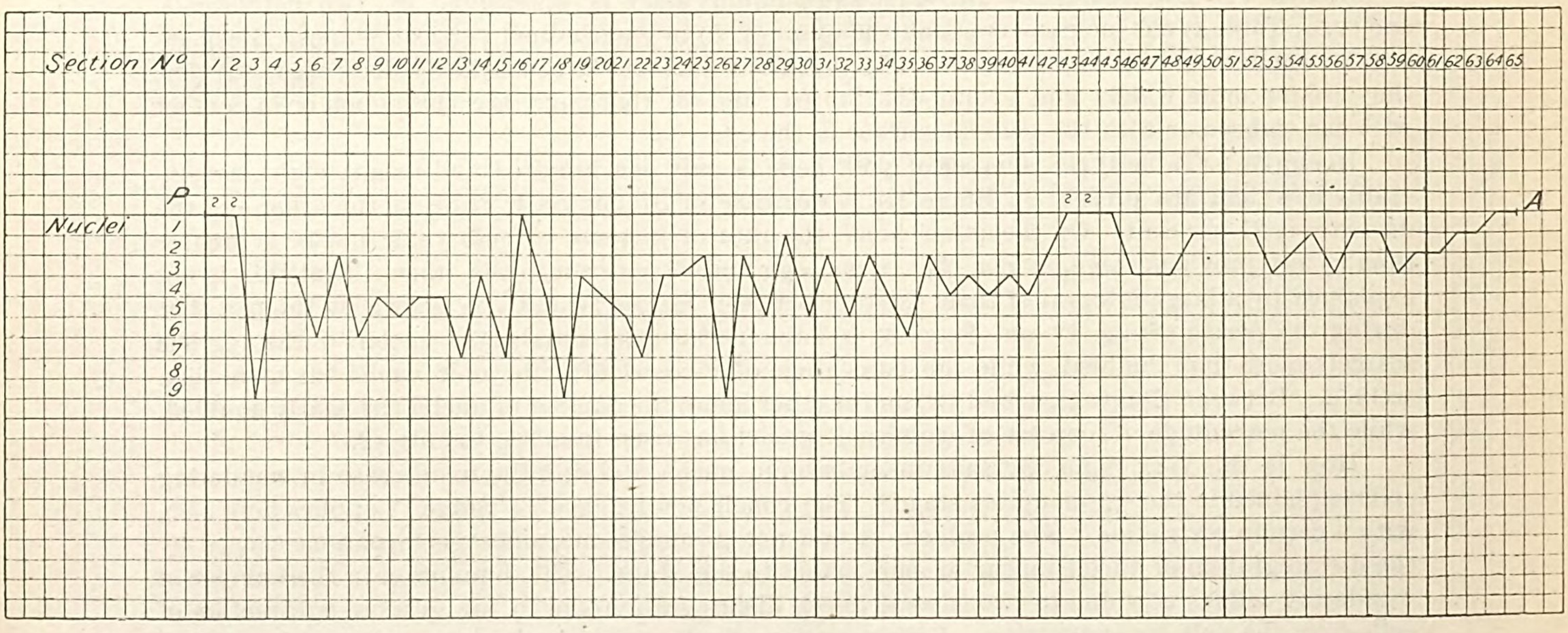


FIG. 13.—Curve showing the distribution of wandering cells in Stage V, *a*. (V. Table I.) A, Anterior; P, Posterior.

of transverse sections, we see that wandering cells are most abundant in the thoracic-abdominal-fold region and in that which answers to the future heart. We also notice the forward extension of migratory cells beyond the anterior edge of the optic lobes. In cut 12 the lateral extension of the nuclei on either side the embryo is well shown. The mouth is involved in section No. 28,

and the embryonic area is included between sections 14 and 41. The marked peripheral distribution of the migratory cells is very significant. There seems to be a general movement of these bodies to all parts of the superficies.

What is the ultimate fate of those cells which wander out to the surface of the egg? Fig. 34, Pl. XXIX, represents part of a section of the extra-embryonic surface at this stage. Here is undoubted ectoblast (Ep.), and cells (Y. C.), which have undoubtedly come from the yolk, are pressing against the surface. In a single egg one may meet with twenty or more such cells, as well as with cells in various degrees of proximity to the surface. Do these cells (Fig. 34, Y. C.) eventually contribute to the mesoblast or ectoblast of the embryo? This question can not be answered by direct observation, since it is clearly impossible to follow the fate of the individual cells. From all the evidence which I have gathered I conclude that the wandering cells give rise to mesoblast—muscles of body wall, connective tissue, and blood corpuscles, and, later, to the definitive entoblast lining of the midgut. The part which the primary yolk cells play can not be decided, nor can it be determined whether degeneration is more characteristic of these elements than of the invaginate wandering cells.

In a lobster's egg at the delamination stage, equivalent to Stage II, Table I, I find 213 nuclei present. Eleven of these belong to the yolk. Upwards of twenty, two of which are yolk cells, are in process of division. Of the eighteen superficial or peripheral cells which are in karyokinesis, two are dividing horizontally or delaminating. In the lobster the primary yolk cells degenerate, in part if not wholly, at a very early stage, as already stated.

In the egg-nauplius phase it was noticed that wandering cells settle down upon the ectoblastic bands out of which the nervous system is subsequently developed (Fig. 127, Y. C.). In this case also it is impossible to ascertain with certainty the fate of such cells. They might form ectoblast or mesoblast, but it is more probable that they contribute to the latter layer only.

It is evident that the history of the wandering cells is largely the history of the mesoblast and entoblast. The mesoblast,* where it has been studied in Decapods, as in Astacus, is found (54) to originate in certain swollen cells in or near the anterior margin of the "blastopore" or pit. From this primary mesoderm cells are budded off, which extend forward in a more or less continuous sheet over the ectoderm. It is possible that in Alpheus the wandering cells may serve as a means of a precocious development of the mesoblast and entoblast. In connection with this idea, it is interesting to recall the fact that in high temperatures of the tropics the developmental stages are passed very rapidly. At Woods Holl, Mass., the late egg-nauplius of the lobster, *Homarus americanus*, is from fourteen to sixteen days old, while a similar stage is reached by *Alpheus saulcyi* at Nassau, N. P., in about seven days.

VIII.—THE DEVELOPMENT OF THE NERVOUS SYSTEM.

The nervous system can be referred back in the embryo to an early stage (Figs. 58, 62, 68), when V-shaped ectoblastic thickenings unite the optic disks to the thoracic-abdominal plate. The intervening space is gradually encroached upon until the optic disks are completely bridged by a dense sheet of ectoderm. There is an apparent concrescence of the limbs of the V, and in the egg-nauplius (Pls. XLI, XLII) these thickenings form a pair of more or less closely united cords, which are separated on the middle line by a median longitudinal furrow. The shallow furrow is formed by the swellings of ectoderm which correspond to the future ganglia, and extends from the supraœsophageal ganglia to the segment of the first maxillæ.

The nervous system of the egg-nauplius is not differentiated from the general integument, and the ectoderm is still a single layer on the middle line in the maxillary region (Fig. 121), while at the base of the first pair of antennæ (Fig. 116) it has the appearance of an elliptical plate in transverse section.

---

* Weldon, whose paper on the germinal layers in Crangon has been referred to, says truly that the difference between invaginated cells is not sufficient to enable one to say that certain cells are endoderm and that others are mesoderm, but he designates as endoderm all cells which are derived from the invagination, and restricts the origin of the mesoderm to the lower layer cells of the ventral plate. Judging from the evidence which has thus far been presented, the cells which he has marked endoderm, lying against the embryo and near the folds of the appendages, are in my opinion to be interpreted as mesoblast. The thoracic-abdominal thickening is composed of a pair of concave "neuro-muscular" or ventral plates, which correspond to the single plate described in Alpheus.

The antennular ganglion is in close union with the optic ganglion and unites also with the antennal ganglion which lies along the sides of the stomodæum, extending slightly behind it.

The histological differentiation of the nervous elements is not very considerable at this stage. In the ectoblastic thickenings, out of which the nervous system is formed, we can distinguish three kinds of cells: (1) the superficial cells, (2) the central cells, and (3) the accessory cells which come from the yolk. These are best seen in a section of the antennular ganglion (Fig. 116). The outer cells (1), which form the integument, possess very large granular nuclei. Some of these, on either side of the middle line, can be distinguished beyond doubt as the nuclei of those large ganglion cells so characteristic of later stages (see Figs. 146, 147, 169, 170, 191, *g. c.*). They possess a more or less definite cell body of a round or oval contour. In preparations this is fine-grained and, like the nucleus, stains but feebly. The weak stain of the nucleus is due to its very fine and loose chromatin reticulum. Karyokinetic figures attest to the multiplication of these cells (Fig. 191), and it is highly probable that they give rise to similar cells which occur in both larva and adult. But what is remarkable in the earlier stages is their enormous size and their peripheral position. Reichenbach calls attention to similar cells in the embryo crayfish, which also arise from the outer layer of ectoderm cells and for a long time help to form the outer wall of the body. It is hardly probable, however, that these cells are relatively more highly differentiated in respect to their ultimate function than any of the surrounding cells which take part in the nervous system. The central cells (2) are the ordinary ganglion cells of the cortex which inclose the fibrous masses. They have smaller and less regular nuclei, which stain very heavily. Cell boundaries are entirely effaced, and the cell protoplasm is reduced to a minimum. The accessory cells (3) rest on the dorsal surface of the thickening, and represent indifferent or wandering cells derived from the yolk (Fig. 116, cts., Pl. XLI, *mes.*). I am not prepared to say that any of the ultimate nervous cells are derived from this source, but I am certain that cells migrate from the yolk and attach themselves to the ectoblastic thickening out of which the nervous system is formed, and that they multiply by indirect division. It is probable that the connective tissue sheaths of the nervous system may be due, to some extent at least, to such cells. The ectoblastic thickening is increased by the radial division of superficial cells and by the horizontal division of the deeper cells.

In the larval and adult stages the large balls of fibrous substance, particularly those of the brain, are surrounded by a delicate cell layer or internal envelope. The nuclei are small and spindle-shaped and form an exceedingly thin sheet. It is possible that this represents intrusive mesoblast, derived from the yolk. Reichenbach states very positively that in Astacus connective tissue cells are squeezed into the fiber balls and eventually surround them. I have no positive evidence to show that the cells in question are not of ectodermic origin, but the behavior of the wandering yolk cells renders it probable that they should rather be referred to the mesoblast of the embryo.

The Punct-substanz of Leydig or fibrous substance is not present at this time, unless it is represented by a very delicate reticulum in the midst of the nerve cells of the ganglia of the first antennæ on their dorsal surface next to the yolk. Degenerating cells (Fig. 114 s^1) occur in abundance close upon the optic ganglia and the ventral ectodermal thickening.

It may be interesting to notice that the structure of the antennular ganglion (Fig. 116) is similar to that of the optic lobe. In either case there is a peripheral tier of cells possessing large granular nuclei, an inner layer with smaller nuclei, and an imperfect layer of investing cells.

Passing to Stage VII (Pl. XLIV) we find the nervous system still very rudimentary. The superficial cells, particularly in the region of the optic lobes and the antennæ, have large nuclei, which can be seen in the act of division, dividing both longitudinally, thus increasing the superficial area of the plate, and also tangentially, in this way adding to its thickness. The very intimate union of the optic ganglion (Fig. 132 *G. L.*) with the antennular ganglion (*S. O. G.*) is still very noticeable, and the delicate investment of these parts on the side of the yolk (*mes.*) is more marked.

Punct substanz has definitely appeared in the supra-œsophageal ganglion where there is a marked transverse commissure, and can even be distinguished in the œsophageal commissures. It forms a very delicate protoplasmic reticulum, and there can be no doubt that the fibrous substance of this part of the nervous system arises as an outgrowth from the protoplasm of ectoderm cells.

The paired structure of the ectodermal plate is well shown in the antennular ganglion on a level with the transverse commissures, or even in front of this, where paired masses, with small, deeply dyed nuclei, are separated by a median sheet of much larger and clearer cells. This may possibly correspond to the mittelstrang, referred to again.

Shortly after this (Fig. 139) the ganglia are blocked off by a series of superficial constrictions. At least seventeen such ganglionic segments can be counted, beginning with the optic and supra-œsophageal ganglia and passing to the last abdominal segments. The ganglionic blocks are formed rapidly from the front backward. The ganglia of the first antennæ are now the most conspicuous part of the nervous system, unless we accept the large optic ganglia. There is a broad, transverse, fibrous commissure in the antennular segment, which is still more prominent at a little later period (Pl. XLVI), when eye pigment is forming. From this commissure longitudinal rods extend forwards and unite the brain with the optic ganglia, while similar rods grow backward and form the fibrous axis of the circum-œsophageal commissures.

The plane of section in Fig. 148 passes just in front of the œsophagus and through the roots of the first pair of antennæ (*A* 1), which should appear in the drawing as continuous with the integument. The ganglionic cells, which are directed toward the appendages, represent the antennular nerves, and are more apparent in the following section. The antennular ganglion is both preoral and preantennal, lying in front of the first pair of antennæ, which it supplies with nerves.

The brain and ventral nerve cord are now plainly separated from the hypodermis, and are bathed throughout their extent with blood plasma, in which numerous blood corpuscles are seen floating at every point. Giant ganglion cells have become most conspicuous in the optic region and at the periphery of the brain next the hypodermis.

The brain is partially divided in front next the optic ganglion by a delicate membrane, which forms a median superficial partition between its two halves. This is continuous, with a delicate envelope, which in some cases can be detected about the brain, and is like that which covers the optic ganglion and nervous system generally. A similar non-cellular membrane at this time divides the retina from the optic ganglion, and is continuous with the cuticular sheath of the latter. The intercepting retinal membrane is directly continuous with the delicate basement membrane of the hypodermis. The cuticular sheaths of the nervous system are present in the embryo (Figs. 157, 168 *pr.*), the larva (Figs. 175, 176), and the adult. It may not seem easy to harmonize this account with the view already taken that the wandering cells attach themselves to the nervous rudiments and form a delicate investment to them (Figs. 129, 131 *mes.*). Such is plainly the fate of some of the wandering cells, but the number of cells is probably too small to form a continuous structure, and it is possible that the delicate membrane secreted by the ectoblast may serve as an accession to that formed by mesoblast.

With respect to insects, Wheeler (67) concludes that in Doryphora the "outer neurilemma" is ectodermic rather than mesodermic in origin, since—

> Shortly after the separation of the nerve cord from the integumentary ectoderm, it sheds from its surface a delicate chitenous cuticle simultaneously with the shedding of the first integumentary cuticle. This cuticle, which is separated from the surface of the outer neurilemma, and even from the surfaces of the main neural trunks, is afterwards absorbed.

At the time when the nervous system has completely separated from the integument there is a slight ingrowth of ectoderm cells along the midventral line, most pronounced between the ganglia, and the appearance of a corresponding constriction on the side next the yolk. In transverse section the nerve cord is somewhat hourglass-shaped. This may be due to a mechanical necessity, arising from a more rapid development of the nerve cells in the lateral masses than in the other parts.

Ectoblast cells derived from the integument appear to be infolded between ganglia (see Fig. 157—a thin sheet of cells, with spindle-shaped nuclei bending in between the last thoracic and first abdominal ganglion, in the lower right hand portion of the figure), but these infoldings may be somewhat deceitful, since they are straightened, to some extent at least, with the growth of the abdomen (Fig. 168, *abg. I*). On the ventral surface of the thoracic region (Fig. 168) spindle-shaped nuclei are seen wedged between the nerve cords on the middle line. It is not, however, certain that these cells are ectoblastic, since the sternal blood sinus is already formed, to which

blood cells have penetrated, and here eventually the sternal artery is developed. While the evidence is not conclusive, we have only to decide between the former conclusion—that the intrusive tissue is derived from the wandering cells, and is to be referred to mesoblast, or the view that it represents differentiated ectoblast.

A general account of the structure of the nervous system of the larva is given in the first section. Further than this the details of development have not been followed.

In comparing this account with that given by Reichenbach for the crayfish, *Astacus fluviatilis*, there are numerous particulars in which there is no agreement, while in some important matters we are in accord.

I find in Alpheus the oral invagination occurring on a line drawn between the bases of the antennular buds, and I have a great many preparations of the eggs of the lobster, *Homarus americanus*, which show the earliest traces of the stomodæum. Before the first antennæ are folded, when they are distinguished as dense patches of cells, some eggs show the primitive mouth as a minute circular pit, lying nearly on a line drawn between the centers of these proliferating cell areas, but, so far as my observation goes, never distinctly in front of them.

The relative positions of the mouth and first pair of antennæ shift very rapidly during the early period of their growth, which precedes the fully developed egg-nauplius condition. The pit elongates and becomes a transverse furrow, and by the time the first pair of antennæ are clearly marked off as rounded buds, and before the second pair are raised into folds, the mouth is still on a line with the first of these appendages. When the second antennæ are elevated into folds the mouth is behind the buds of the first pair, or on a line between their posterior edges.

Reichenbach (taf. II, Fig. 7*a*, L*b*.) describes and figures a cell thickening between the "Kopflappen" of the crayfish embryo (Stage E), which he considers the beginning of the labrum. His sections show that below this point a mass of ectodermic cells occurs, which is interpreted as the "Vordarmkeim." The mouth is not represented as appearing until the following egg-nauplius stage (Stage F. Compare Fig. 66 and p. 100, § 7, "Der Vorderdarm"), when it occupies a position exactly comparable with that observed in the lobster. I therefore can not agree with Kingsley in saying that Reichenbach "has all the appendages at first distinctly postoral." While the position of the Crustacean appendages may have been primitively postoral, it may be questioned if in the higher Crustacea the first antennæ ever arise behind the mouth invagination.

Kingsley describes the position of the mouth in Crangon as distinctly postoral, but an inspection of figure 11 of his paper, leaves some doubt as to whether he is not mistaken in this particular. A single rudimentary appendage, marked as the first antenna, is represented as occupying nearly the entire space between the optic disk and thoracic abdominal fold. This does not agree with my own preparations,* and since in Alpheus, Homarus, and Astacus the mouth does not appear until a dense stratum of cells carpets the intermediate space between the optic disks and lateral cords, there is some difficulty in interpreting the cluster of cells marked *m*, in Kingsley's paper, as the invagination of the mouth.†

In Alpheus, Homarus, Astacus, and probably in Decapods generally, the ganglion of the first antenna cannot be said to be postoral, but its development begins nearly on a line with the invagination of the primitive mouth. The ganglion of the second antenna is developed behind the primitive mouth, but gradually shifts forward with its appendage until it comes to lie, in the larva, considerably in front of the mouth. In this movement, the ganglion however outstrips the appendage. The ganglia of these two appendages unite to form the brain or supra-œsophageal ganglion. The ganglion of the first pair of antennæ is constricted into two portions marked by an oblique, transverse line at the surface. The anterior of these parts Reichenbach calls the

---

* I have preparations of the eggs of *Crangon vulgaris*, in various stages of development, from the segmentation onward. In one egg, which is somewhat more advanced than that of figure 10 (31), or than the Alpheus in Fig. 58 of this paper, the optic disks and ventral plate are dense patches of cells. On either side of the ventral plate and in close relation to it there is a marked area of cell proliferation which represents the mandible. In the space between this and the antenna the nuclei are more scattered, but the karyokinetic figures show the activity of cell division. In a late nauplius stage the stomodæum is on the middle line between the first and second antennæ, and the antennular ganglion is segmented into two parts on each side, as shown for Alpheus in Fig. 110.

† This criticism is supported by Weldon's observations on Crangon, who, with reference to this subject, says: "The first antennæ are evidently præoral from the very earliest period at which the mouth is visible." Op. cit.

"vordere Hirnanschwellung" and the posterior the "Seitenanschwellung," using the terms of Krieger and Dietl. These latter particulars accord with Reichenbach's description of the crayfish. I have not, however, found that in Alpheus, behind the level of the first pair of antennæ, the lateral parts (Seitenstränge) divided up into three sections. Reichenbach further states that in each segment a middle-strand invagination is found, while the ganglia of the fifth (first maxillary) segment has a prominent median string.

In Alpheus I find an undoubted median ingrowth of surface ectoblast between the two nerve cords. This in all probability corresponds to the mittelstrang, and, as already stated, it is most marked at a stage just before or at the time of the first appearance of the eye pigment, when the ganglia are separating from the integument. It is seen between the successive segments of the ventral nerve cord, where a single cell or string of several cells appears to be wedged between the two cords which are entirely separated (compare Figs. 151, 160). The nuclei of these cells are elongate and perpendicular with the surface. They are derived by delamination from the superficial ectoblast, as the karyokinetic figures of dividing cells clearly show. These ingrowths are most noticeable between the segments, and whether they form any part of the nervous system or not, I have been unable to determine. In insects the mittelstrang appears to take no part in the nervous system of the adult, but in the thoracic region it is converted into the chitenous furcæ.

According to Reichenbach the lower œsophageal ganglion in the crayfish is formed by the fusion of the ganglia of the fourth (mandibular) to the ninth (third maxillipedal) segments. This is probably true of Alpheus, as may be inferred from Fig. 196.

With reference to the commissures, Reichenbach states his belief that the transverse commissures originate in the unpaired fiber masses present in each ganglion, while the paired masses give rise to longitudinal commissures. In Alpheus there appear in successive segments behind the mouth a pair of punctsubstanz balls, one ball in each single ganglion. These extend forward and backward, uniting the ganglia into chains and forming the longitudinal commissures. A little later the transverse commissures are formed by bridging the cords between the points occupied by the fiber-substance balls in the several ganglia. All these stages can be observed in the embryo shown in Fig. 139, but all do not appear in the drawing.

The origin of the peripheral nervous system is beset with many difficulties. It is often impossible to distinguish developing nerves from rudimentary connective tissue and muscle, owing to the similarity of the nuclei of each. This is less true of muscles, which in some parts of the embryo, as in the carapace, are clearly distinguishable. In view of this, Reichenbach found it difficult to say whether the nerves were budded off from the central nervous system, from other ectoderm, or from wandering mesoderm cells. He thinks, however, that since many structures like the optic ganglion, the crystalline cone cells of the retina, etc., are early recognizable, the nervous system is generally in intimate connection with the other organs. So the appendages, the nervous system, and the nerves, which at first can not be distinguished from each other, are intimately connected from the start; so the eye and the ear are never separated from the central nervous system. The separation of the central nervous system from the skin takes place slowly, and the ectodermal thickenings in the early stages must conceal the rudiments of nerves and skin elements. It is difficult, he remarks, to understand the late connection of the midgut with the central nervous system and the scattered mesoderm cells which form the muscles, but he says, in conclusion:

> Bei der Unterschung der wunderbaren Entwicklungserscheinungen in der organischen Welt aber drängt sich bei tieferer Betrachtung immer wieder der Gedanke auf, dass man schon vom ersten Stadium an einem untrennbaren Ganzen gegenübersteht. (54, p. 80.)

This view of the intimate colonial relations of all the cells of the embryo can not be disputed, since it follows from the common descent of all the somatic cells from the ovum. But the relation which the embryonic cells bear to each other as the undifferentiated ectoblast to mesoblast must be of a very different nature from that which exists between muscle fiber and nerve in the differentiated state. It seems more probable that the union of the central nervous system with other organs by means of nerves is strictly a secondary one, and that the latter arise by budding, as in vertebrates, from the central ganglia. The only observations which I have made on the development of nerves (see section I) refer to those of the first and second antennæ (Pl. LV, Figs. 213–216, *n. au.*, *n. a. g.*; Pl. LVII, Fig. 243, *n. au.*). The antennular nerve, which supplies

the ear, appears to arise as an outgrowth from the antennular fiber mass of the brain (Fig. 243, *af.*). It consists of a fibrous portion leading directly from the fiber mass of the brain and of somewhat flattened, or spindle-shaped nuclei, which penetrate the cortex of nervous cells and are undoubtedly proliferated from them. Possibly the internal sheath is continued over the growing nerve.

IX.—THE EYES.

The eyes in Decapods consist of a pair of lateral compound eyes, which in the larva are mounted upon long stalks, a condition usually retained in the adult, and of a median ocellus. In the Alpheus family the compound eyes are nearly sessile and are completely hooded by the carapace. In the larva, however, the eyes are both naked and possess long, movable peduncles (see the metamorphosis, Pl. XXI). In *Alpheus saulcyi* the optic stalks are reduced to a mere rudiment, and, though provided with muscles, they can possess but very slight power of movement. They meet on the middle line in front of the brain, over the roots of the first pair of antennæ. The compound eyes face forwards and outwards at an angle of 45° with the mesial plane of the body. A median papilla projects from below the lateral eyes, bearing the pigmented ocellus (Figs. 209, 210, of larva). Two small hairy tubercles, outgrowths of the integument, occur on the inner side of the optic stalk.

Spence Bate (3) says that since the Alphei are frequently found in ooze and muddy bottoms, he is inclined to think that they burrow more extensively than the common shrimp, and that the carapace has become modified to protect the eyes on this account. This may be true, but the Squillæ, on the other hand, in which the burrowing habit is more characteristic, have undergone no such modification.

THE MEDIAN EYE.

The median "nauplius" eye persists in the adult Alpheus, and is probably functional to some extent as a visual organ. This is represented in Fig. 18, Pl. XXII, where it is seen as a small conical papilla, lying between the basal joints of the antennules, and at the roots of the compound eyes, very close upon the brain. This is the first instance I have noticed of the persistence of the nauplius eye in the adult.

The general position of the median eye of the first larva of *Alpheus saulcyi* is seen in Figs. 209 and 210, and the minute structure in Fig. 197. The pigment takes the form of an inverted Greek capital upsilon (Υ). There is no lens. A coaguable fluid is present, which is probably blood plasma. Besides muscle-fibers and pigment-secreting cells, and the integumentary epithelium, these ectodermic nerve end (?) cells, which abound toward the center of the papilla, are continous backward into the cortical cells of the anterior fiber mass of the brain.

The first trace of the frontal eye which I have noticed occurs in the tenth stage (Fig. 168), when a small number of cells developing black pigment (probably ectodermic) can be seen near the surface, on the middle line, next the anterior extremity of the brain.*

GENERAL ANATOMY OF THE EYESTALK.

The visual apparatus of the compound eye of a Crustacean consists of three principal parts, the retina, the optic ganglion, and the optic nerve, uniting retina with ganglion, in addition to a peduncle of nerve fibers, which puts the optic ganglion in communication with the brain. These parts are contained in the eyestalk or opthalmite. The eyestalks are covered with a cuticle secreted by the ectoderm like that over the rest of the body. This cuticle, which in some prawns like Stenopus is hard and armed with spines, is converted at the distal, hemispherical surface of the stalk into a transparent cornea. The ectoderm or hypodermis secretes a well defined basement membrane. This is continuous with the basement membrane of the retina, pointing clearly to the fact which development proves, that the retina is a differentiated portion of the hypodermis. Below the basal membrane we meet with blood vessels or sinuses, muscles which control the movements of the eyestalk, glands, connective tissue, ganglion cells, and fibrous substance.

* While this memoir was in press a short paper appeared in the *Quarterly Journal of Microscopical Science* (January, 1892), "*On the Nauplius Eye persisting in some Decapods*," by Margaret Robinson. The median eye was observed in some eight different species of the Caridida, including the genera Palæmon, Hippolyte, Virbius, Crangon, and Pandalus.

Alpheus in the only genus in which I have found glands in the eyestalk. These are most noticeable at the peripheral parts of the stalk between the basement membrane and the ganglia. They are in reality parts of the green gland, which sends outgrowths from the bases of the second antennæ into the antennules, the eyestalks, the labrum, and the whole front of the head, so as to completely envelope the brain. The histology of the glandular coeca is the same in all parts. They consist of a cubical epithelium, composed of very large cells, supported by a basement membrane.

Near the coeca of the antennal gland comes a layer of very loose connective tissue. This is specially abundant below the basement membrane of the retina. It forms a continuous sheath for the optic ganglion, and is reflected over the optic peduncle and brain.

By far the greater mass of tissues of the eyestalk belongs to the optic ganglion. This is composed of ganglion cells (Fig. 187), nerve fibers, and the peculiar fibrous tissue variously called "Punct-substanz" or "Ball-substanz," and "substance ponctuée." Viallanes, who has made very careful and detailed studies of the optic ganglia of Arthropods, uses the following terminology (61). He divides the optic ganglion into two parts, an external and an internal portion. The surface of the external region is covered by the limiting membrane of the eye. The external is united to the internal parts by a bundle of crossing fibers, the *external chiasma* (Fig. 178, Ch. Ex.). This, according to Viallanes, corresponds to the center of the corneal surface, and consequently to that of the limiting membrane of the eye. The internal portion between the external chiasma and the optic peduncle is composed of three principal masses of punct-substanz: (1) la masse médullaire externe, (2) la masse médullaire interne, (3) la masse médullaire terminale. The external medullary mass is united to the masse médullaire interne by an *internal chiasma*, while a fibrous peduncle joins the internal medullary mass to the masse médullaire terminale. The nerve fibers which pass between retina and ganglion, he calls the post, retinal fibers, and designates as "optic nerve" the peduncle by which the optic ganglion is united to the brain. The distal mass of punct-substanz is styled lame ganglionnaire,* which he divides into a nuclear layer (couche à noyaux), a molecular layer (couche moléculaire), and a cellular layer (couche à cellules ganglionnaires).

The punct-substanz of the optic ganglion is thus divided into four principal masses (Figs. 178, 209). Without adhering closely to the rather cumbrous terminology of Viallanes, the parts of the nervous system contained in the eyestalk between the brain and retina may be designated as follows: *Optic peduncle* (optic nerve of Viallanes and others); *proximal segment* (masse médullaire terminale); *internal middle segment* (masse médullaire interne); *external middle segment* (masse médullaire externe); *distal segment* (lame ganglionnaire); *optic nerve* (couche des fibers post-rétiniennes).

GENERAL STRUCTURE OF THE COMPOUND EYE.

The transparent cornea is the secreted product of a specialized layer of the hypodermis, which was designated by Patten as the "corneal hypodermis" and later as the "corneagen" (50, 51). Beneath this lie several strata of dioptic and sensory cells, separated from the ganglion by a basement membrane, which is continuous with that of the general hypodermis of the eyestalk. The ommateum, or eye proper (including those parts which intervene between the cornea and basal membrane), is formed by the repetition of a highly specialized unit, the eyelet or ommatidium. The size, number, and arrangement of the ommatidia is characteristic of species or genera, but is subject to considerable variation in different individuals, and the shape and arrangement of the ommatidia may be very irregular in different parts of the same eye. The ommatidia are differentiated clusters of ectoderm cells. There is a single ommatidium for each lens or corneal facet. The number of cells composing the ommatidium is very uniform in Decapods, Stomatopods, and Schizopods, so far at least, as the most essential cells are concerned. They are as follows: Cells of corneal hypodermis, 2; crystalline-cone cells, 4; outer pigmented retinular cells, 2; inner pigmented retinular cells, 7 (functional); Accessory pigmented cells—irregularly distributed, both above and below the basement membrane, probably of ectodermic origin.

---

* The lame ganglionnaire is called "Retina ganglion" by Claus, who regards it as the true retina; "das aussere Ganglion opticum" by Carrière, and "periopticum" by Hickson.

STRUCTURE OF THE OMMATIDIUM.

Both a lack of time and of fresh material have prevented me from making as thorough a study of the structure of the ommatidium of Alpheus as I had wished. The following account is based entirely upon sections:

The corneal facet is strongly biconvex (Fig. 200), the convexity of the lower side being the greatest. Its shape is usually hexagonal, but may be tetragonal, or sometimes nearly circular (as in *A. heterochelis*). There are two corneal cells to each lens. A single ommatidium is shown in Fig. 200. As in all Decapods, the cone cells which underlie the corneagen are four in number. The four segments of the crystalline cone (Fig. 208), which are secreted on the inner sides of the latter cells, are always separated by delicate boundary lines. The cone is capped by a mass of protoplasm in which the nuclei of the cone cells lie, although it is not always easy to distinguish them. This cap appears to be raised into a slight elevation which touches the center of the lens.

Pigment cells invest the cone more or less completely according to the conditions under which the eye is examined. These are the retinular cells. In the larva, and probably in the adult also, there are two distal retinular cells (*pg.* c Pl. LIV), as Parker (48) designates them, and at least seven proximal retinular cells (*rtl.*). Parker discovered in Homarus and several allied forms a rudimentary eighth cell belonging to the proximal series. This is present I believe, in Alpheus, although my sections do not show it with the same clearness that it can be demonstrated in Palæmonetes. The seven proximal retinular cells secrete on their inner sides the rhabdom or rhabdomeres. A transverse section of the rhabdom gives the peculiar seven-pronged figure shown in the drawing (Fig. 205). The cells appear as fused in section, but possibly they would separate with readiness if macerated. Unfortunately I had no fresh material to experiment with. The proximal retinular cells appear to penetrate the basement membrane, and they are continuous below it with nerve fibrils. As to their distal ends, I have seen no evidence that they extend out to meet the cornea. The retinular cells abound in dark pigment.

The accessory pigment cells secrete a peculiar pigment which is glistening white in reflected light and is amber color in transmitted light. This may be similar to the pigment of certain cells which occur beneath the cuticle of the larva of Decapods in various parts of the body. It is not decolorized when subject to the prolonged action of weak solutions of nitric acid, while the black pigment is completely removed. What I once regarded as chitinous bodies (20–21) were fused masses of this pigment which had been treated with nitric acid. These cells penetrate the basement membrane, beneath which there is a considerable mass of both yellow and black pigment. The trains of cells which accompany nerve fibrils into the fibrous portions of the optic ganglia also contain granules of black pigment. The number of accessory pigment cells belonging to each ommatidium is indeterminate. They have the power of free movement or migration outward from the basement membrane and the power of retraction like the retinular cells. In Fig. 200 they are seen widely diffused, while there is a zone of black pigment cells (the pigment withdrawn by acid) enveloping nearly the entire cone and the distal end of the rhabdom. In an eye taken from a prawn which had just moulted, the yellow pigment was restricted to a narrow zone next the basement membrane. Outside of this belt the retinular cells were colorless nearly up to the proximal ends of the cones, while the cones themselves were draped in black.

ARRANGEMENT OF THE OMMATIDIA.

In *Alpheus saulcyi* the ommatidia are arranged in a hexagonal system, subject to variations in different parts of the eye.* In the central parts of the cornea the facets are symmetrical hexagons. On the lower side of the eye the rows are more irregular and individual facets tend to become square and rounded. Toward the outer side of the eye the facets are very nearly square, next to these they become irregular and rounded, and on the extreme outer edge the facets are sometimes hexagonal. There is probably considerable individual variation. I have examined the cornea in four other species of Alpheus, namely in *Alpheus heterochelis*, *A. minor*, *A. normani*, and a West Indian species closely allied to *A. heterochelis*. These cases afford some very interesting

* For a study of the cornea, adults of the largest size were selected and the cuticle was cleaned by boiling in a concentrated solution of potassic hydrate.

facts in connection with the arrangement of ommatidia. In *Alpheus normani* the facets are generally symmetrical hexagons, two of the sides being quite short. These tend to run into squares or rounded areas at parts of the periphery. *Alpheus minor* has the facets in the lower part of the eye either of the hexagonal or some polygonal form, while in the upper and outer parts the facets are perfect squares. These blend on all sides into symmetrical hexagons. The first transition from the hexagon to the square is seen on the outer edges of this area where the individual facets become more and more rhomboidal, as the two opposite sides of the hexagon are more and more reduced. Finally these sides disappear and the facets become rectangular. The square facets of any given row now lie opposite to those of the adjoining rows. Four facets belonging to any two rows meet at a common point. In passing, however, from the area of square facets to the peripheral parts, the facets, though square, are out of line. Starting from a point where the facets of a given row are both tetragonal and opposite those of adjoining rows, and following the line over the hemispherical surface toward the periphery, the facets of this row soon tend to become alternate with those of the row next to it. A facet of the second row lies slightly in front of the corresponding facet of the first row. The facet of the third row lies a little in advance of this and so on until the hexagonal shape is gradually assumed.

In the Bahaman variety of *Alpheus heterochelis* the facets in the larval eye are markedly hexagonal. In the adult there is the same curious transition from the hexagon to the square as we have noticed in *Alpheus minor*, only it is here much more striking. In the peripheral parts of the eye, especially in the lower and inner portions, the facets are generally hexagonal. In the upper half of the eye between the center and periphery there is a small area of square facets. In *Alpheus heterochelis* the facets are characterized by much greater looseness of arrangement, there being large interlenticular spaces. The facets are squares with rounded corners. In some parts of the eye, as on the inner lower side, the facets of the adjoining rows lie opposite each other. In other parts they regularly alternate and show a tendency to become hexagonal. At the periphery the facets are widely separated and circular.*

The markings on the corneal lenses generally consist of a small central spot which is slightly elongated and strongly refracts the light. It appears in section to represent a slight depression. In the lobster, as first shown by Parker, there is a faint diagonal band which intersects a central hazy spot and divides the square into equal triangles. These diagonal bands are all parallel in adjoining rows. In *Alpheus saulcyi* the elongated spots, if continued across the lens, would form a series of similar diagonal lines, but none such as these could be detected. In *Alpheus heterochelis* the markings are very constant and peculiar. In the center of the lens there is a large irregular impression from which numerous rays extend on all sides. The latter do not always reach the periphery. They appear like grooves in the substance of the lens. In the older embryo (Fig. 194) the apex of the cone cells seems to touch the under side of the lens in certain parts of the eye. It is therefore possible that these cells remain in contact with the cornea and the interference thus caused gives rise to the spot. A similar explanation is offered by Parker to account for the conditions found in the lobster. The significance of the radiating lines seen in *Alpheus heterochelis* I have not determined.

In Homarus the facets are square and grouped with remarkable regularity up to the very edge of the cornea, excepting at a point on the upper side, where a peninsula of tough cuticle juts in from the surface of the stalk and interrupts the elliptical jet black area of the surface of the eye. About this process, particularly in front of it, the facets are hexagonal or irregular and very much smaller.

Parker (48) states that in the lobster "the ommatidia rearrange themselves between the times when the young animal is 1 inch and 8 inches long. During this period the ommatidia increase about ten times in length and about five times in breadth." I find that this rearrangement begins at a much earlier period, in fact in the older larval stages. My examination comprised the following stages: (1) Length 8–9^{mm} (first larval stage); (2) length 11^{mm} (fourth larva); (3) length 15.3^{mm} (sixth larval stage); (4) length 49^{mm} (lobster 1 year old).

---

*A similar transition of the square into the hexagonal facet in the same eye occurs in Astacus. See Howes' Biological Atlas, Fig. 111.

In the first larva of both *Homarus* and *Alpheus saulcyi* I find that the facets are not only hexagonal but tend also to be slightly rounded. In the larva 11^{mm} long the lenses tend to become square toward the center of the cornea, while at the periphery they are smaller and generally hexagonal. Occasionally, however (just in what part I did not ascertain), the peripheral facets tend strongly to the tetragonal arrangement. In the next case (larva 15.3^{mm} long) the facets in the outer parts of the eye are small and symmetrical hexagons. Toward the center they become larger, nearly square, and there is considerable interlenticular space.

In the yearling lobster the readjustment of the corneal lenses from the hexagonal to the tetragonal system has been effected over the greater portion of the eye, but the transition is still illustrated in a very beautiful manner. The cuticular ingrowth or peninsula, already referred to, seen at the upper surface, is hook-shaped, bending backward. In the open angle in front the retina is least differentiated. The corneal facets in this region are small and mostly hexagonal. Following the lines of facets as they curve outward and backward from this point over the convex surface of the eye, we see illustrated in a very striking way the passage of the hexagon into the square by the gradual reduction of the opposite sides. The sides which are sacrificed are the third and sixth, counting from the side which lies between two adjoining lenses of the same row. Over a considerable area the facets are not quite square and thus tend to alternate with those of adjoining rows. The gradual transition to the square is attended by a gradual increase in size. In the narrow angle behind the peninsula, the area of the hexagonal facets is smaller. In all other parts of the periphery the facets are square up to the very edge, as in the adult. The corneal lens in an 8-inch lobster has about twice the area of that of the lobster one year old (length nearly 2 inches).

After reviewing these details the difficult question arises: What is the significance of this remarkable change, and how is it effected?

Parker (48), who has made a careful study of the arrangement of the ommatidia in different Crustaceans, recognizes two plans on which these organs are grouped, the hexagonal and the tetragonal. He says that "in the Brachyura, as well as in three families of the Macrura, the Hippidæ, Paguridæ, and Thalassinidæ, the arrangement of the ommatidia is invariably hexagonal. In the remaining macrurous Decapods the ommatidia are grouped on the tetragonal plan." There are, however, exceptions to the latter statement, some of which are mentioned. He regards the change from the hexagonal to the tetragonal system as apparently due to the increase in size and the consequent crowding of the ommatidia, and reaches the conclusion from the various facts presented, that the hexagonal arrangement is phylogenetically the oldest. Upon this view we should expect to find the eyes of the most highly differentiated of the Crustacea arranged on the tetragonal system, whereas in points of fact the crabs, who are notorious for their great activity and keen powers of vision, permanently adopt the hexagonal arrangement. The lower Macrura adopt both methods, and in certain species of Alpheus, as *Alpheus minor*, which are active in habit and show no trace of degeneracy, the change is begun but not completed in the same retina. In order of time the hexagonal prism precedes the square prism and the conditions which determine the permanency of each of these systems in the adult life of the individual are undoubtedly inherited, but they do not appear to have a phylogenetic significance, at least I do not see the way clear to an explanation upon this ground.

Taking, for example, the lobster and the crab, in each case the larval eye represents, we must believe, the more generalized type, the adult eye the more specialized type. The larval eye of both Macrouran and Brachyouran has the hexagonal facet. We may safely conclude that this is a primitive arrangement. The adult crab, which has a more highly organized nervous system and keener senses, retains this primitive arrangement, while the lobster, whose senses are without doubt duller, departs from the type, and in the adult the facets of the cornea take on a permanent tetragonal shape. The conditions which we would naturally look for are thus reversed in these two forms.

We must assume that the change in the case of the lobster is a useful variation, that it is in some way subservient to keen vision, otherwise it could never, upon the theory of natural selection, have secured such a permanent characteristic footing. On the other hand we must believe that the hexagonal facet puts the eye of the crab into better harmony with its environment than the square facet would do, for if the eye had not been in harmony with external conditions it must

have varied and attained to a new structure during the course of the evolution of the Brachyoura from Macrouran ancestors.

Many crabs like the sand crab, *Ocypoda arenaria*, spend a good portion of time out of the water and their eyes are admirably adapted for vision in the air, as in the case of this species, which will detect any moving object, such as a man or a dog, a long distance off. We might thus hope to find a way of escape from the difficulty in the diversity of habits in the two forms, the lobster being exclusively an aquatic animal. But the primitive Crustacea must have all been aquatic, and the hermit crabs, some of which spend all or nearly all of their time in the water, agree with the Brachyoura in having a corneal membrane composed of hexagonal facets, not to speak of other Macrouran forms which are invariably aquatic, like Alpheus, in which the hexagonal system is retained or there is a transitional condition between the hexagon and the square in the eye of the adult.

We do not yet know the physical or physiological significance of these two kinds of facets, and possibly in this fact lies the root of the difficulty pointed out above.

The hexagonal arrangement is the natural one for tubes with elastic walls to assume when there is sufficient mutual pressure, and it is also the most economical arrangement, so far as wall space is concerned, for regular prisms of equal capacity. Next to this in point of economy of wall space comes the square prism, and next to this the triangular prism, where, as before, all available space is occupied. This last arrangement, however, is not regularly assumed.

If a given number of hexagonal prisms occupying a given space tend to increase in size, then they would tend also to assume another form less economical of wall space, such as the square prism. If the wall area of the hexagonal prism remains the same and the number of prisms increases in a given space, then each prism must be less economical of wall area and assume another form like that of the square prism.

If we may apply the same principles to the growing ommatidia, it is possible that crowding may have something to do with the change.

In the lobster the change from the hexagonal to the tetragonal system is attended by a growth of the ommatidium in all directions and by the addition of new ommatidia. If an outline drawing of the eye of the first larva of the lobster be compared with a similar one of the fifth larva, it will be seen that the convexity of the outer surface, that is, the area of the eye, has very greatly increased, whereas the diameter of the eye stalk has remained very nearly the same. During this period the change from the hexagon to the square has been begun. During this time the ommatidia have increased in length with the increasing convexity of the cornea, and they have also increased in sectional area and in actual number. It is a very noticeable fact also that in the lobster the eye stalk is compressed dorso-ventrally, so that the horizontal radius of curvature of the retinal surface is considerably greater than the vertical radius of curvature. Furthermore, the sides of the hexagonal facets which suffer reduction lie in a vertical plane, indicating a strain or pressure in a dorso-ventral direction.

In *Alpheus saulcyi* the relative increase in the convexity of the corneal cuticula is very slight in passing from the first larva (length, about 4^{mm}) to later stages, and the eye of an adult (13^{mm} long) is only about one-fourth larger than that of the larva at the time of hatching. Moreover, in Alpheus the convex surface of the eye is nearly a perfect hemisphere, the curvatures being the same in every plane.

If we examine the eyes of a crab in a similar way we find that the area of the surface of the retina increases less rapidly in passing from the zoëa to the megalops stage than in the case of the lobster in going from the first to the fourth larval forms. The comparison, however, is of little value since the lobster has an abbreviated development. The eye stalk of the adult crab presents a large retinal surface, but it preserves a nearly cylindrical form, although the radii of curvature of the retinal surface are very unequal. In the hermit crab (in a single species examined) the hexagonal arrangement is preserved, not, however, without indications of a tendency to become tetragonal, the hexagons becoming asymmetrical in certain parts of the eye. There is, however, the same compression of the eye stalk in a dorso-ventral plane as we see in the lobster.

It has seemed to me worth while to point out these facts as offering some suggestions to the problems under discussion, although I make no attempt at a mechanical explanation.

The primitive arrangement of the ommatidia was probably in the form of simple tubes or cylinders, with spaces between them and with rounded or indefinite facets. Mutual pressure among these tubular eyelets, arising from any cause, produces the hexagonal arrangement, the most economical method so far as wall space is concerned. Interferences such as have been suggested, as growth of individual ommatidia or increase in the number of ommatidia in the same area, thus admitting a method of arrangement less economical of wall space, or the great increase in length of the ommatidia and a relatively less increase in width, attended by a progressive change of the hexagons into squares (the apparent slipping of the rows of facets on one another), may enter as factors into this change, but they do not suffice to explain all the conditions. It will be understood, of course, that there are no changes in the individual facets, these remaining in the same shape until they are cast off in the moult. The changes which the individual ommatidia undergo are very gradual, and since the number of cells for each ommatidium is constant and determined at a very early period, excepting the accessory pigment cells, they must be attributed to the change in the size and relative positions of the cells themselves rather than to intussusception. It is possible that the change from the hexagon to the square is not produced in the same way in all cases and that the conditions of growth which bring about this result are far more complicated than would appear from the suggestions which have been made. A careful study of the arrangement of cells in the ommatidia of the eye of the young lobster during the period of transition would possibly throw some light upon this interesting subject.

THE DEVELOPMENT OF THE COMPOUND EYE.

Five years ago (20) I stated my conviction that the compound eye of Alpheus, and probably also of Palæmontes and of the large Isopod, *Ligea oceanica*, originated from a thickening of the superficial ectoblast. The development of the eye in Alpheus was more fully described in a preliminary notice (21). I will now recapitulate the main results, at the same time correcting such errors as I have detected.

In studying the development of the eye the following are some of the subjects which present themselves for investigation: The origin and structure of the optic disks; the separation of the optic disks into a ganglionic and retinal portion by an intercepting basement membrane; the differentiation of the retina into ommatidia or eyelets; the differentiation of the optic ganglion and the development of the optic nerve, by means of which the sensory end organs of the retina come in direct relation with the ganglion.

(1) *Origin of the Optic Disk.*—The optic disks (Fig. 58, Pl. XXXII) consist of large ectodermic areas or patches on either side of the middle line. They are centers of rapid cell division, united by means of the lateral cords, which are bands of proliferating cells, with the thoracic-abdominal plate.

So far as I am aware we have no account of the origin of the optic disk in any Decapod excepting Alpheus, Astacus (54), Crangon (30), and Homarus (47). Parker, in his careful studies on the eye of the lobster, was unable to obtain the earliest traces of the developing optic disk, and the accounts of Reichenbach and Kingsley differ very materially. I will therefore describe somewhat in detail the process by which the optic disk is produced in Alpheus.

The optic disks at the time when they consist of a single stratum of cells are shown in Figs. 58, 68, and 69. A series of four transverse sections through the central portion of the left optic disk is represented in Figs. 64–67. The posterior face of each section is presented, the series passing from the front backward.

Since it is from the optic disk that the eye and its ganglion are developed, the important inquiry which arises at this stage is, how is the change effected by which the disk passes from this single-layered to a many-layered condition like that seen in the egg nauplius (Figs. 107, 114)? If the eye represents a series of hypodermal pits, it would be reasonable to look for some trace of these infoldings in the embryo. If, on the other hand, the compound eye of the higher Crustacea represents a closed vesicle produced by a single invagination of the hypodermis, of the type seen in the prototracheate Peripatus, we should expect to find some trace of an involution at this stage. So the answer to this question may have an important bearing upon the phylogeny of the compound eye.

Cell boundaries are easily discernible at the surface, but it is evident that the nuclei do not

all lie at the same level. Passing now to Stage IV (Fig. 72), we notice several important changes in the external appearance of the optic disks. They have approached nearer the middle line; they have increased in area; their nuclei are more crowded; near the center of the disk and on the side of it toward the middle line (Fig. 72, *C. M.*) the nuclei are distinctly larger. In interpreting these changes we must resort to sections and a careful study of dividing nuclei. A complete series of consecutive transverse sections through the left optic disk at this critical stage is given in Pl. XXXV. The last of the series cuts the rudiment of the first antenna. Karyokinetic figures come to our aid in pointing out the way in which the growth of the disk is effected. The nuclei divide either radially, the plane of division, clearly marked by the equatorial plate, being perpendicular to the surface, or horizontally, the plate being in this case parallel with the surface. In a single disk at this stage there were eight cells undergoing radial division. Of these, six were near the periphery, where the cells formed a single stratum, while two were near the center, where the disk was slightly thickened (Fig. 80, *C. M.*). It is evident from this and similar cases that the increase in area of the disk is accomplished by radial cell division. The same is true of all proliferating areas in the lateral cords, where the appendages are soon budded.

In the area marked *C. M.* (Fig. 80) the optic disk is no longer a single layer. This thickening is due either to horizontal cell division, that is, delamination, or to emigration. The appearances of emigration are often very deceitful, but I think we may safely conclude that the initial thickening of the optic disk in the proliferating area, marked *C. M.* (Figs. 80, 90), is due to emigration, that a solid ingrowth akin to invagination takes place at this point. Thus the cell marked *ec* in Fig. 80 is distinctly below the surface. The boundaries of the cell can be clearly seen. The cell *ec* in Fig. 90 (dotted line should be extended), on the other hand, is clearly in contact with the surface by a slender protoplasmic process, while the nucleus lies at a much lower level. I interpret the latter as a cell at the point of breaking all connection with the surface and migrating to a lower position. In the first instance this has already been accomplished.

In the stages under discussion there are one or two cases out of a large number of sections involving the optic disks of several individuals, which probably indicate delamination in the peripheral parts. At a later period (Figs. 102–107) the nuclear figures are conclusive. In one instance (Fig. 102, *ec.*) two cells are seen delaminating side by side. The thickening of the optic disk is thus due in part to delamination, and this process is probably supplemented by emigration, at least in the central area. The central area represents in all probability the "optic invagination" of the crayfish, and is concerned solely with the production of the optic ganglion. In Alpheus there is a proliferating area simply, but no superficial depression or invagination in the strict sense.

It is noticeable that in Stage III (Pl. XXXIII) wandering cells, or cells which travel through the yolk, have not appeared in the neighborhood of the optic disks. In Stage IV (Fig. 70, *Y. C.*) they are not far away, and in later stages (Fig. 91) these cells are close upon the disks. Some of them which enter this region, coming near to or uniting with the disks, undoubtedly degenerate (compare *Y. C.*, Fig. 94, s–s^1, Figs. 95, 96, 99, 100). Some of the cells of the disks next the yolk elongate, and appear to form a somewhat transitory covering. As already suggested, these bodies are probably derived from the wandering cells.

The various stages by which the disk, already described, is converted into a conspicuous lobular mass of cells in closest relation with the antennular ganglion such as we have in the egg-nauplius (Fig. 111, *O. L*), can be seen by reference to the plates (Pls. XXXVI–XL).

(2) *The Development of the Retina and Optic Ganglion.*—The next event of importance is the differentiation of the optic disk into ganglionic and retinal portions. This is already begun in Stage VII. A deeper layer from which the ganglion is developed (Figs. 129, 132, *G. L.*) is gradually separated from a superficial tier of cells with very large nuclei (*OE*). This layer is the retinogen. The differentiation begins in the lateral lower halves of the optic disks and extends upwards and toward the middle line. As the disk spreads outwards, and at the same time increases in thickness, it tends to overgrow the hypodermis and becomes raised into a lobe or fold. The optic lobe (Figs. 136, 138) thus represents a thickening of the hypodermis. It is covered next the yolk by a delicate basement membrane (*Bm.*), which is continuous with that of the surrounding hypodermis.

Wandering cells are seen in contact with this membrane (Fig. 136), but they probably do not share in its secretion, although they occur in the closest relations with it.

At a little later period (Fig. 138) the retinal portion is several cells thick on the outer edges of the lobe, while it is a single stratum in the sagittal section, shown in Fig. 138. The plane of section is near the center of the lobe. The deeper nuclei of the ganglion are large and clear, the outer are smaller and stain more intensely. This section can be clearly understood if compared with the transverse section, Fig. 146. We see that the optic ganglion is here divided into an external or distal part and an internal or proximal portion by a thin sheet of very large and clear ganglion cells. Parker (47) describes and figures an exactly similar structure in the lobster, and I fully agree with him in regarding this band of nuclei as representing similar bands, which Reichenbach (Taf. XII, Figs. 173, 174, *A. W. I. W.*) describes in the crayfish. In Reichenbach's plates these nuclei appear as a narrow fold, forming the lining of what is described as a secondary optic invagination.

Three punct-substanz masses have already appeared in the inner half of the optic ganglion, the external middle segment, which lies next to the band of large nuclei, and the internal middle and proximal segments. The proximal medullary mass is much the largest and is the first to be differentiated, although the others follow close upon it. The dividing nuclear band lasts but a short time, and in Stage 10 (Fig. 167) has disappeared. In front of it is developed the lame ganglionaire or distal segment of the optic ganglion. This has an outer convex surface which is concentric with the basal membrane and with the outer surface of the retina, and it is carpeted by a special layer of ectoderm cells. These appear in section as a single row of elongated nuclei.

In an early communication (20) I stated my belief that the punct-substanz arose from a metamorphosis of ganglion cells. This view was suggested by certain appearances presented by the large clear nuclei, more particularly by those of the dividing band in the optic glanglion (see Fig. 180). Kingsley (32) came to the same conclusion in regard to certain large clear nuclei in or near the distal segment of the optic ganglion of Crangon. In reviewing this subject more carefully I am convinced that this interpretation is erroneous. These large clear cells are in reality undergoing indirect cell division, as proved by the karyokinetic figures which are occasionally seen. Both the chromatin network and the chromosomes are exceedingly delicate, and when the section is in the plane of the equatorial plate an appearance is presented which under certain conditions of staining and preparation might easily be interpreted in favor of retrogressive metamorphosis. I conclude that the punct-substanz of the nervous centers is in all cases derived from the protoplasm of cells, not from cell nuclei.

In Stage IX when eye pigment first appears, the structure of the retina is very simple. By the transverse section (Fig. 146), we see that the retina consists of a thickened ectoderm plate, thickest in its deeper portions, thinning out toward the middle line at the surface. It has the shape of the half section of a concavo-convex lens.

In Palæmonetes the structure of the eye is precisely similar at this stage. Fig. 189 gives a section of the eye of this prawn, on a line with the œsophagus behind the optic ganglion, where it is seen to rest against the yolk. The black pigment, though appearing to arise in connection with certain mesodermic cells (wandering cells from the yolk), it in reality belongs to deep ectoderm, and marks the retinular cells. The cell protoplasm bearing the pigment bodies grows outward (Fig. 146), and also pierces and extends some distance below the basement membrane (Figs. 191, 192). The latter is a delicate cuticular structure secreted by the ectoderm cells which lie along the line of division of retina and ganglion, and continuous with the basement membrane of the hypodermis. In some sections it appears to be duplex, a condition described for the eye of the lobster by Parker (47), in which the inner layer enfolds the optic ganglion. The wide open fissure which now exists between retina and ganglion (seen in transverse section at *an*, Fig. 136) is partially filled with yolk. There is not the slightest doubt that cells enter this fissure from the yolk (Mes. Figs. 146, 167, 189, 194, etc.), but what the fate of these wandering bodies is, I find it very difficult to decide. I think, however, that it can be stated definitely that none of these cells enter the retinogen. They must supply some of the pigment found in this region, or they may become converted into connective tissue. In Stage X (Fig. 167) the yellow accessory pigment cells are clearly differentiated, or at least the pigment which these bodies give rise to, is seen

in abundance around the retinular elements. This is without doubt ectodermic in origin. Some yellow pigment also occurs below the basement membrane. This may be ectodermic or mesodermic, but the great bulk, if not all the accessory pigment cells, which in the adult eye extend their processes through the basement membrane, are ectodermic in their origin.

At the edge of the retinal plate the cells become very much elongated (Figs. 146, 188), and finally can no longer be distinguished from the superficial ectoderm. The thickening of the retinal plate is due solely to emigration. This might be inferred by the interwedging of the nuclei (Figs. 188, 189), and it is proved in cases of cell division by the position of the equatorial plate, which is always perpendicular to the surface.*

A later stage in the development of the eye is illustrated by Figs. 190 and 191, which are anterior (superficial) and posterior (deep) transverse sections. In Fig. 190 we see the retina differentiated into cell clusters. Each cluster represents part of an ommatidium—the corneal hypodermis, the cone cells, and possibly the distal retinular cells. The lower stratum of small nuclei belongs to the proximal retinulæ and to the accessory pigment cells. In deeper section, Fig. 191, we distinguish the proximal retinulæ—black, rod-shaped bodies piercing the basal membrane. The nuclei lie at the distal extremity of the pigment. Between the pigmented parts of the retinular cells other nuclei occur, which possibly represent an eighth rudimentary retinular cell (rtl^1). At the surface of the eye there is a stratum of cells with elongated nuclei. These are the nuclei of the corneal cells and probably also of the distal retinulæ. Between this and the inner stratum of retinular nuclei, the nuclei of the cone cells are seen, and a granular substance which is probably the first trace of the peculiar secretion of these cells. In an older stage represented by the drawing (Fig. 192) we see all these parts in a higher degree of development, and the eye has grown out into a very prominent lobe. Fig. 167 is intermediate between this and Fig. 191. The central parts of this eye are the most highly developed, and as we pass to the periphery especially away from the middle line, the ommatidia are less and less developed, until they reach the condition of a single layer of undifferentiated ectoderm. Thus, in a single section (like Fig. 192), we have a sort of composite picture of the various stages through which the developing retina has passed.

A considerably older stage is reached in Fig. 194. The cells of the corneal hypodermis are quite large and have already secreted a cuticular lens. The nuclei of the cone-mother cells are also conspicuous.

Later still, when the embryo is nearly ready to hatch, the eye has undergone very slight change. Fig. 187 represents an oblique longitudinal section through the eye stalk of *Alpheus heterochelis*. The black pigment of the retinular cells has been removed by the action of the nitric acid. Irregular sheets and masses of yellow pigment occur both above and below the basement membrane. The conspicuous stratum of nuclei, in which the bases of the cone cells are embedded, belong to the proximal retinular cells. The nuclei (unrepresented) lie close to the surface between the corneal cells. The cone cells end distally in a conical cap of protoplasm, the apex of which touches, in some cases at least, the corneal facet. The proximal ends of the cone cells taper gradually and can not be traced below the pigment zone.

In the first larva of *Alpheus saulcyi* the structure of the eye is similar. This is illustrated in Figs. 201–204 and Fig. 209. In transverse section (Fig. 201) the corneal cells are crescent-shaped. The distal retinulæ lie in the same plane with the latter and have the peculiar arrangement shown in the drawing. They are grouped in pairs, so that each set of corneal cells is surrounded by six nuclei—two pairs of nuclei and two single nuclei. The two odd nuclei pertain to the ommatidium in question. The delicate membranes which appear to surround the corneal cells belong, in all probability, to the distal retinular cells.

The structure of the compound eye has become a favorite subject of research during the past five years, and the important study of the development of the faceted eye, about which very little was known when Balfour's "Comparative Embryology" appeared, has not been neglected; still much work needs yet to be done in this direction. The literature of this subject has been recently examined by Parker (48), and I will therefore add to this account only a few comparative notes.

---

* Parker states that the corneal hypodermis arises in the lobster by simple delamination. (*Op. cit.*) I have never seen delaminating cells in any part of the retina of Alpheus or Palæmonetes.

The proliferating areas in the optic disks of Alpheus and Homarus are undoubtedly homologous, and probably correspond also to the optic invaginations described in Astacus by Reichenbach and in Crangon by Kingsley. I therefore agree with Parker (47) in interpreting the ingrowth or involution of ectoderm, whichever may occur in the developing disk, as concerned with the optic ganglion solely and not with the retina. Reichenbach describes the visual organs as originating from three factors: (1) an epidermal layer; (2) the optic invagination; (3) the optic or segmental ganglion. From the epidermal layer and outer wall of the optic invagination the retina arises, while the inner wall of the secondary invagination unites with the optic ganglion. An inspection of Reichenbach's Fig. 224 (54) shows, as Parker has pointed out, that in all probability Reichenbach has misinterpreted his sections, and that the entire retina is derived from the hypodermal layer. The layer of cells with elongated nuclei, which he has designated as rhabdom, clearly pertains to the optic ganglion, and probably represents the nuclear covering of the distal convex surface of the lame ganglionaire (Fig. 192 of this work).

Kingsley, in his third paper on Crangon, changes his interpretation of the invagination of the optic disk of Crangon, regarding this involution as concerned only with the optic ganglion I am inclined to believe that a renewed study of this subject would show that the optic disk originates in Crangon precisely as it does in Alpheus. A series of sections through the thickening disk of Crangon has little to show which is not brought out by a similar series of Alpheus (Figs. 76–83), and no pit or hollow invagination is seen.

The independent origin of the optic ganglia lends some support to the view that they have a segmental value and are not merely outgrowths from the brain, that the eyestalk is a modified appendage containing its proper ganglia.

Watase's interesting views (63) concerning the origin of the ommatidium from a hypodermal pit do not receive the support we should expect from embryology. How much value is to be given to the embryological data in this case it is hard to say, but, seeing the persistence of the involutions in the eye of Limulus, we would expect to find a trace of similar infoldings in the developing eye of the lower Crustacea, provided their eyes are constructed upon the same type. Until greater evidence is furnished I am inclined to regard the "compound eye" not as an aggregate of simple eyes, as the name implies, each one of which is due to a hypodermal infolding, but rather, as Parker has suggested, to differentiated clusters of ectoderm cells originating from a single epithelial layer.

THE EYE UNDER THE INFLUENCE OF LIGHT AND DARKNESS.

In June, 1890, while enjoying the facilities for biological research afforded by the laboratory of the U. S. Fish Commission at Woods Holl, Mass., it occurred to me that some valuable experiments could be made by testing the effects of direct sunlight and total darkness upon the growth and behavior of the pigment cells of the compound eye of Crustacea. After finishing my experiments upon one form I learned of the experimental work of Exner* upon the eyes of the glowworm, *Lampyris splendidula*, of Hydrophilus, Dysticus, and Colymbetes, in which he records the same phenomenon in insects which I have observed in a Crustacean. Later a paper has also appeared, by Mademoiselle M. Stephanowska, on the histological arrangement of pigment in the eye of Arthropods. I have seen only an abstract of this work, from which I gather that it deals either largely or entirely with the eyes of insects. My experiments were made upon the common prawn, *Palæmonetes vulgaris*.

A dark chamber was constructed and rendered as absolutely light-proof as possible. Inside of this a small glass aquarium was so arranged that a stream of sea water could be kept running through it for any length of time. Three egg-bearing females were then placed in the aquarium and the chamber was sealed. The egg embryos were early nauplius stages. Females with eggs in a similar stage were also kept under observation in an aquarium exposed to the light. The general cast of color of the prawn taken in the light is some shade of light brown or brownish green. After spending eighteen days in the dark, the prawns were taken out and exposed to the moderately bright light of the laboratory. The eyes were jet black and appeared to have greatly

* Since these notes were written I have received the completed work of Exner, *Die Physiologie der Facettirten Augen von Krebsen und Insecten*, in which the field of experiment is greatly enlarged.

swelled in size, and the body was bleached nearly white. *The peculiar appearance of the eyes was caused by the forward extension of the distal retinular cells, of which there is a single pair in each ommatidium.*

The eggs of some of the prawns were hatching, and the pigment of the zoëa was carefully compared with that of the first larva of Palæmonetes hatched in the light. Both the black pigment of the retinular cells and the yellowish green pigment of the accessory pigment cells of the eye and the large brown chromatophores in different parts of the body were of the same character, whether the embryo had developed in darkness or light.

Another prawn was kept in the dark thirty-eight days, and on exposure to the light it presented the same appearance. As in the other cases, as soon as light reached the eye the distal retinulæ began to retreat to a deeper level. At first the black pigment which characterizes these cells extends out to the cornea. After an exposure of two minutes to direct sunlight a slight transparent band is seen below the cornea. This light zone increases as the pigment continues its retreat until, in the course of three-quarters of an hour, the distal retinulæ ensheath only the lower ends of the cones.

In another experiment a prawn was left only about twenty-four hours in darkness. The same effects were produced in the eye, which assumed its former condition after being in the diffused light of the room twenty-five minutes. The distal retinular cells thus respond very promptly to the action of the light, and in the course of a few hours (the exact time needed was not determined), if excluded from the light, completely enshroud the proximal ends of the cone cells.

In the eye of Palæmonetes, taken in ordinary daylight, there are three distinctly marked strata of pigment between the basement membrane and the cornea, a proximal narrow stratum of yellowish brown pigment belonging to the accessory pigment cells; a wider and much lighter area peppered with dark granules, pertaining to the proximal retinular cells, the nuclei of which form a conspicuous belt or layer on a level with the distal extremity of the rhabdoms. Lying close upon the tier of retinular nuclei is a thin stratum of intensely black pigment, composed of the distal retinular cells. As stated above, there are two of these cells to each ommatidium, and they each send out a slender thread-like process, which extends in some cases as far forward as the corneal cuticula, where it is possibly attached. I have not detected any similar prolongations in the direction of the basement membrane. Below the level of the cone, which terminates abruptly in a convex proximal surface, the cone cells are prolonged into a long slender stalk consisting of protoplasm or of a refractive substance of a different nature from the cone. The cone cells are not apparently prolonged below the level of the retinular nuclei. The distal retinular cells thus surround the proximal ends of the cone cells.

In the eye exposed for thirty-eight days in the dark the distal retinular cells form a stratum about midway between the corneal cuticula and the layer of nuclei of the proximal retinular cells. The nuclei occupy a central position in this layer. Pigmented pseudopodia extend forward to the cornea, and occasionally a cell shows a slight inward prolongation. Had the eyes been preserved without bringing them into the light, even for a moment, the distal retinular cells would undoubtedly have occupied a still more peripheral position.

In the eye kept in the darkness for the same length of time and afterwards exposed to the light for five hours the distal retinular cells have retreated until they lie around the proximal ends of the cones. The nuclei of these cells lie immediately upon the nuclei of the proximal retinular cells, and it is interesting to notice the pigmented body of each cell folded on itself. In section the pigment takes the form of plaited black ribbons. When the eye is again stimulated by light the ribbon unfolds as the cell travels forward.

These cells are called by Exner the iris pigment, since they regulate the brightness of the retinal image in much the same way as the vertebrate iris does.

X.—SUMMARY.

In the review, including Sections V–IX of Part Second of this memoir, the principal embryological facts have been summarized, and it will now suffice to recapitulate only some of the more interesting results.

PART I.

Metamorphosis.—(1) The majority of the Alphei hatch as zoëa-like larvæ, while two species are known, *A. heterochelis* and *A. saulcyi*, in which the metamorphosis is abbreviated. This shortening of the metamorphosis appears to be directly related to the habits and environment of the species. *A. heterochelis* has one metamorphosis at Beaufort, North Carolina, a more abbreviated development at Key West, Florida, and, if we are right in considering the Bahaman form as a member of this species, at Nassau, New Providence, the metamorphosis is complete or unabbreviated. The Nassau form of *Alpheus saulcyi* either has the metamorphosis greatly abridged or it hatches with all the external characters and the instincts of the adult. When we inquire into the modes of life of these species we find the remarkable fact that the Nassau *Alpheus saulcyi* is a parasite or commensal, living in the pores of certain sponges, and the metamorphosis is completely absent or profoundly modified. The Floridian *Alpheus heterochelis* is a parasite in sponges, and has its metamorphosis greatly abridged. The Beaufort *heterochelis*, which must be regarded as descended from the Floridian stock, has its metamorphosis less abridged than in the latter case and it is nonparasitic. However, we still find it occasionally producing small eggs, indicating a tendency to revert to the old metamorphosis, long since abandoned. Even if we decide that the Nassau *heterochelis* has had a different genealogy from that of the Beaufort variety, we still have strong evidence to show that the metamorphosis of the species may change in accordance with a change in habits and environment.

Variation and Habits.—(2) *Alpheus heterochelis* of Beaufort presents an interesting variation in the structure of the small chela, which appears to be a sexual one.

(3) In many Macroura as well as Brachyoura, and especially in the Alpheus, one of the claws is enormously enlarged, often nearly equal in size to the rest of the body of the animal. This great chela may be either on the right or left side of the body, but it almost invariably follows that all the young of a brood have the large claw on the same side, indicating that this characteristic is inherited from the parents, and that where both of the latter have the right or left claw enlarged they give rise to right and left handed broods, respectively.

(4) *Alpheus saulcyi* presents very profound variations, and some of these varieties would undoubtedly be regarded as distinct species by systematic zoölogists if the intermediate forms were unknown. These forms are described and discussed in Sections V and VII of Part First.

Species living side by side show no tendency to commingle, and hence we conclude that the striking varieties which we are here met with are not the result of hybridism, but are confined to a single species. Two well-marked varieties occur, which I have distinguished as *Alpheus saulcyi*, var. *brevicarpus*, and *A. saulcyi*, var. *longicarpus*. Between these forms every intermediate stage is found.

The color variations in this species are also exceptionally marked. In all respects the males appear to be more variable than the females. The structural peculiarities of the mother appear to a large extent in the offspring, and if the swamping effects of intercrossing should be eliminated it is likely that this species would soon become separated into at least two distinct forms.

It seems most probable that the change in habits or environment which this species has undergone, has acted as a direct stimulus to variation.

PART II.

Structure of the Larva of Alpheus saulcyi.—(5) The structure of the first larva of this Alpheus reaches a very high degree of complexity, which is but little exceeded by that of the mature adult form.

The green gland does not yet appear to have an external opening. The five pairs of gills present at this time are also rudimentary, and the reproductive organs are only represented by a small cluster of large cells on either side of the middle line, between the digestive tract and the anterior end of the heart. For the histological details, reference must be made to Section I of Part Second.

The Ovary and Ovarian Egg.—(6) The ovary consists of an external stroma of muscular and connective tissue and a lining epithelium. The ova arise from the lining epithelium, and each egg

is differentiated from a distinct epithelial cell, the nucleus of the cell becoming the nucleus or germinal vesicle of the egg. Some of the epithelial cells enwrap the developing ovum and form the follicle or pocket in which it is lodged. The chorion or inner egg membrane is the direct secretion product of the follicular cells.

(7) In Homarus and Palinurus the character of the germinal epithelium is somewhat different from that of Alpheus. The outline of individual cells is obscured and the germinal epithelium extends inward from the wall, in the form of radial sheets or folds, between which are reëntrant blood vessels. There are a number of germogenal areas corresponding to the folds in which the ova originate. During growth the eggs gradually pass from the center toward the periphery. In the germogen the cell outlines are obscured.*

(8) The yolk arises within the cell protoplasm, and in Homarus degenerating nuclei occur in the ovarian stroma, and it is probable that a certain number of nuclei degenerate and enter into the food yolk of the egg. In the lobster also some of the follicle cells develop into gland-like structures which characterize the mature ovary. They appear to have a direct relation to the growing eggs, but their true significance has not yet been ascertained. In about two weeks after the eggs have been extruded these structures have almost wholly disappeared.

(9) I have observed a single polar body in a section of the egg of Stenopus, in which the male and female pronuclei were present, and two polar bodies in the ripe unextruded egg of the lobster. In lobster's eggs also which failed of extrusion at the proper time, and which eventually degenerate in the ovary, I find that the nucleus is at the surface. It has the appearance of a female pronucleus. It is thus probable that the polar bodies are often, if not always, given off before the eggs are laid.†

Segmentation in Alpheus minor.—(10) The segmentation in *Alpheus minor* is in some respects anomalous, and the conclusion seems to be warranted that we have here a case of amitosis, unlike anything which has been hitherto described in Crustacea. Unfortunately my material is not at present sufficient to enable me to say in exactly what way the usual process of cell division has here been modified.

Delamination.—(11) The segmentation has been thoroughly reviewed in Section v, and it is unnecessary to repeat the details. I wish to call attention, however, to the fact that at the close of segmentation in the lobster some of the blastodermic cells delaminate and their products pass into the yolk. In *Alpheus saulcyi* a similar migration of cells from the superficial to the deeper parts of the egg occurs, but in this case it was not determined whether this migration was preceded by delamination or not. These cells appear to originate in greatest number over that side of the egg which corresponds in position to the embryonic area. It seems possible that these cells may represent a primitive endoderm, the function of which has been usurped. In the lobster they speedily degenerate.

Invagination Stage.—(12) The invagination stage, which soon follows, results in the admission of more cells into the yolk and in the formation of an organ called in this memoir the ventral or thoracic-abdominal plate. Cells also continue to pass into the yolk from the ventral plate. While cells are constantly being subtracted from the plate, it is constantly receiving new recruits from the surface, owing to the activity of cell division in this region. We thus have in Alpheus a multitude of migrating cells, derived originally from three sources: from the blastoderm, from the cells which are first invaginated, and from those which originate later from the ventral plate, after all trace of the superficial pit has disappeared.

Germ-layers.—(13) These migrating cells, which are collectively called "the wandering cells" in Section VII, spread to all parts of the egg. While it is perfectly obvious that these bodies represent mesodermic and endodermic tissues, it is not so easy to determine what particuiar cells give rise to this or that layer, nor is it easy to decide in many cases, from a superficial study, whether migrating cells may not be derived from the ectoderm in various parts of the embryo. This sub-

*The structure of the ovary of the lobster has been recently described by Bumpus in a detailed paper upon the embryology of this species. He has called attention to the folded character of the ovarian epithelium, which is so marked in the young or immature ovary. (The Embryology of the American Lobster, by Hermon Carey Bumpus, *Journ. of Morphology*, Vol. v, No. 2, 1891.)

† Polar bodies have been recently described in the external eggs of the lobster by Bumpus. *Op. cit.*

ject is fully considered in Section VII, the general results being: (1) That it is not possible to decide what part the primary yolk cells play in Alpheus, for reasons which have been already considered; (2) that the great bulk of the cells which migrate forward from the area of invagination and attach themselves to the embryo, or proceed to the peripheral parts of the egg and take up a position at the surface, are undoubted mesoblastic elements; (3) that those cells which give rise to the endodermal epithelium in the egg nauplius are derived largely from cells which migrate in a posterior direction from the area of invagination; (4) that degeneration, followed by the death and dissolution of the chromatin and cell protoplasm, is characteristic of the wandering cells at about the beginning of the egg-nauplius period. The mesoblast has become a well-recognized layer before the endodermal epithelium has appeared.

(14) The egg, with centrally moving cells which have budded from the blastoderm, may be compared with the *planula* stage of Cœlenterates, and the internal cells may represent the primitive endoderm. According to this view, the invagination stage has no reference to an adult gastrula-like ancestor, but is a purely secondary condition, which became so impressed upon the ancestors of the present Decapods that it has remained in their ontogeny.

In the majority of Decapods which have been studied the invagination has no direct relation to the mouth or anus, or to the alimentary tract. The conditions which are present in the crayfish cannot be regarded as typical or primitive.

(15) In Alpheus and Homarus the primitive mouth arises on a line between the rudiments of the first pair of antennæ, but these appendages are never post-oral. The hind gut originates as a nearly solid ingrowth, apparently at a point considerably behind the position of the pit due to the first invagination, and is formed one or two days later than the mouth.

Cell dissolution.—(16) The degeneration of embryonic cells is treated at length in Section VI. It is remarkable that the early segmentation stages of *Alpheus minor* are attended with the degeneration of protoplasm. The chromatin residues remain for some time in the yolk, and eagerly react upon dyes, but gradually lose this power and eventually enter into the general nutrition.

(17) Degenerating cells appear in greatest force in Alpheus, Astacus, and Homarus at about the egg-nauplius stage, and from that time their numbers begin to wane. They appear in one instance before the differentiation of the germinal layers, and are not confined to any one layer at a later period, but in *Alpheus saulcyi* they are most characteristic of the wandering cells, which represent mesoderm and endoderm. The "secondary mesoderm cells" and "white-yolk elements" which have been described by Reichenbach, are to be regarded as degenerating cells. Degenerating cells also occur in connection with the "dorsal plate."

The Eyes.—(18) The details of the structure and development of the eyes and nervous system are fully reviewed in Sections VIII and IX.

The eyes and optic glanglia are derived from the optic disk, in the formation of which there is in Alpheus no proper invagination. The thickening of the disk is accomplished by emigration from the surface and by the delamination of superficial cells. An area of active cell division can be distinguished, which corresponds to the invaginate area of the optic disk of the crayfish. The cells which migrate from the center give rise to the rudiment of the optic ganglion. The disk grows out in the form of a lobe, and becomes differentiated into an outer retinal layer and an inner ganglionic layer. The eye proper is differentiated from the retinogen, which is primitively a single layer of ectodermic cells.

(19) I am inclined to regard the "compound eye" not as an aggregate of simple eyes, as its name implies, each of which is due to a hypodermal infolding, but rather as a collection of differentiated clusters of ectoderm cells, originating in a single epithelial layer.

(20) The absence of light has no appreciable effect on the development of the eye pigment, but in *Palæmonetes* the distal retinular cells respond very promptly to the action of light. If the light is excluded from the eye, these cells migrate outward and enshroud the proximal ends of the cones, sending out pseudopodal prolongations to the cornea. When the eye is again stimulated by light the pigment immediately retreats from the surface, and the cell takes the form of a plaited black ribbon, leaving the cones free.

ADELBERT COLLEGE,

XI.—REFERENCES.

1. Bate, C. Spence. On the Development of the Crustacean Embryo, and the variations of form exhibited in the Larvæ of thirty-eight genera of Podopthalmia. Abstract. *Proc. Roy. Soc.*, Vol. xxiv, p. 375. 1876.
2. ———. Report of the Present State of our Knowledge of the Crustacea. *Rept. of 50th. Meet. of Brit. Ass.*, pp. 230–241. 1880.
3. ———. Report on the Scientific Results of the Voyage of *H. M. S. Challenger* during the years 1873–1876. Zoology, Vol. xxiv. Text and separate volume of Plates. *Report on the Crustacea Macrura dredged by H. M. S. Challenger during the years* 1873–1876, pp. i–xc, 1–942. 76 figures and 157 plates. 1888.
4. Boas, J. E. V. Kleinere carcinologische Mittheilungen. Ueber den ungleichen Entwicklungsgang der Salzwasser- und der Süsswasser-Form von *Palæmonetes varians*. *Zool. Jahrb.*, Bd. 4, H. 4, pp. 793–805. Taf. xxiii, Holzschn. 1–4. 1889.
5. Bobretzky, N. Zur Embryologie des Oniscus murarius. *Zeit. f. wiss. Zool.* Bd. xxiv, pp. 179–203. Taf. xxi, xxii. April, 1874.
6. ———. Development of Astacus and Palæmon. Kiew, 1873. Abst. by Hoyer in *Hoffmann and Schwalbe's Jahresberichte.* Bd. ii, pp. 312–318. 1875.
7. Brooks, W. K. The Metamorposis of Alpheus. *Johns Hopkins University Circulars*, No. 17. 1882.
8. ———. Lucifer, a Study in Morphology. *Phil. Trans. Roy. Soc.*, Pt. i, pp. 57–137, Pls. 1–11. 1882.
9. ———. A preliminary abstract of researches by W. K. Brooks and F. H. Herrick on the Life History of Stenopus. *Johns Hopkins University Circulars*, Vol. viii, No. 70.
10. Bruce, Adam Todd. Observations on the Embryology of Insects and Arachnids, pp. 1–31+10, Pls. i–vi. *Memorial Volume, Johns Hopkins University.* Baltimore, 1887.
11. Bullar, J. F. On the Development of Parasitic Isopoda. *Phil. Trans. Roy. Soc.*, Vol. clxix, pp. 505–561, Pls. xlv–xlvii. 1878.
12. Claus, C. Untersuchungen über die Organisation u. Entwickelung von Branchipus und Artemia, nebst vergleichenden Bemerkungen über andere Phyllopoden. *Arbeit. Zool. Inst. Wien*, Tom. vi, Heft 3, pp. 267–370, Taf. i–xii. 1886.
13. Dietl, M. J. Untersuchungen über die Organisation des Gehirns wirbelloser Thiere. ii Abth. (Crustaceen), pp. 1–20, i Taf. *Sitzb. der k. Akad. der Wissensch.*, Bd lxxvii, i Abth. 1878.
14. Dohrn, Anton. Untersuchungen über Bau und Entwicklung der Arthropoden. Zweites Heft, Zur Entwicklungsgeschichte der Panzerkrebse (Decapoda Loricata), pp. 105–128, Taf. x. Leipzig, 1870.
15. Erdl, M. P. Entwicklung des Hummereies von den ersten Veränderungen im Dotter an bis zur Reife des Embryo, pp. i–x, 11–40, Taf. i–iv. München, 1843.
16. Faxon, Walter. On some Young Stages in the Development of *Hippa*, *Porcellana*, and *Pinnixa*. *Bull. Mus. Comp. Zool.*, Vol. v, No. 11, pp. 253–268, Pls. i–v. 1879.
17. ———. On the Development of *Palæmonetes vulgaris*. *Bull. Mus. Comp. Zool.*, Vol. v, pp. 303–330, Pls. i–iv. 1879.
18. Guerin, M. F. E. Méneville. Animaux articulés à Pieds articulés, in *Histoire Physique, Politique, et Naturelle de l'Ile de Cuba*, by Ramon de la Sagra.
19. Heathcote, F. G. The Early Development of Julus terrestris. *Studies Morph. Lab'y Univ. Cambridge*, Vol. ii, Pt. i, pp. 219–240, Pls. xxii–xxiii. 1884.
20. Herrick, F. H. Notes on the Embryology of Alpheus and other Crustacea, and on the Development of the Compound Eye. *Johns Hopkins University Circulars*, Vol. vi, No. 54, pp. 42–44, Figs. 1–8. 1886.
21. ———. The Development of the Compound Eye of Alpheus. *Zool. Anz.*, No. 303, Figs. 1–5. 1889.
22. ———. The Abbreviated Metamorphosis of Alpheus and its Relation to the Conditions of Life. *Johns Hopkins University Circulars*, Vol. vii, No. 63, pp. 34–35. 1888. In the same number are Notes on the "Habits and Color Variations" and on the "Development of Alpheus."
23. ———. The Reproductive Organs and Early Stages of Development of the American Lobster. *Johns Hopkins University Circulars*, Vol. x, No. 88, pp. 98–101. See also No. 80 of *Johns Hopkins University Circulars*, 1890, and *Zool. Anz.*, Nos. 361, 362. 1891.
24. Heider, K. Die Embryonalentwicklung von Hydrophilus piceus L. Erster Theil. Jena, 1889, pp. 1–98, Taf. i–xiii.
25. Howell, W. H. The Life-History of the formed Elements of the Blood, especially the red blood Corpuscles. *Journ. of Morphology*, Vol. iv, No. 1, pp. 57–116, Pl. iv. June, 1890.
26. Huxley, T. H. The Crayfish. *Int. Sci. Ser.*, Vol. xxviii. New York, 1880.
27. Ishikawa, Chiyomatsu. On the Development of a Fresh-water Macrurous Crustacean, Atyephira compressa, De Haan. *Quart. Journ. Micros. Sci.*, Vol. xxv, New Ser., pp. 391–428, Pls. xxv–xxviii. 1885.
28. Kent, W. Saville. Sound-Producing Arthropods. Letter in *Nature*, Vol. xvii, p. 11. 1877.
29. Kingsley, J. S. A Synopsis of the North American Species of the Genus Alpheus. *Bull. of the U. S. Geol. and Geog. Survey of the Territories*, Vol. iv, No. 1, Art. vii, pp. 189–199.
30. ———. The Development of the Compound Eye of Crangon. *Journ. of Morphology*, Vol. i, No. 1, pp. 49–64, Pl. ii. September, 1887. See also *Zool. Anz.*, Jahrg. ix, No. 234, pp. 597–600, 1886, and *Amer. Naturalist*, Vol. xx, pp. 862–867. October, 1886.
31. ———. The Development of Crangon Vulgaris. Second paper. *Bull. Essex Inst.*, Vol. xviii, Nos. 7–9, pp. 99–153, Pls. i–ii. Salem, July, 1886.

32. ———. The Development of Crangon Vulgaris. Third paper. *Bull. Essex Inst.*, Vol. XXI, Nos. 1–3, pp. 1–42, Pls. I–III. 1889.

33. KRIEGER, K. R. Ueber das Centralnervensystem des Flusskrebses. *Zeit. f. wiss. Zool.*, B. XXXIII, pp. 1–70, Taf. XXXI–XXXIII. 1879.

34. LEBEDINSKI, J. Einige Untersuchungen über die Entwicklungsgeschichte der Seekrabben. *Biol. Cent'blt.*, B. X, Nos. 5 and 6, pp. 178–185. 1890.

35. LEREBOULLET, A. Recherches sur le Mode de Fixation des Œufs aux fausses pattes abdominales dans les Écrevisses. *Ann. de Sci. Nat.*, IV Sér., T. 14, pp. 359–378, 1 Pl. 1860.

36. ———. Recherches d'Embryologie Comparée sur le Développement du Brochet, de la Perche et de l'Ecrevisse. *Mém. prés. par divers Savants à l'Acad. des Sci. de l'Inst. Impér. de France*, T. 17, pp. 447–805, Pls. 1–6. Paris, 1862.

37. LOCY, W. A. Observations on the Development of Agelena naevia. *Bull. Mus. Comp. Zool.*, Vol. XII, No. 3, pp. 63–103, Pls. 1–12. 1886.

38. LUDWIG, H. Ueber die Eibildung im Thierreiche. Arbeit. aus dem zoolog.-zootom. Inst. in Würzburg, B. I, pp. 287–510, Taf. XIII–XV. 1874.

39. MAYER, PAUL. Zur Entwicklungsgeschichte der Dekapoden. *Jenaische Zeit. Naturwiss*, B. XI, pp. 188–269, Taf. XIII–XV. 1877.

40. MERESCHKOWSKI, C. VON. Eine neue Art von Blastodermbildung bei den Dekapoden. *Zool. Anz.*, No. 101, pp. 21–23, Figs. 1–8, V Jahrg. 1882.

41. MORGAN, T. H. A Contribution to the Embryology and Phylogeny of the Pycnogonids. *Studies from Biol. Lab'y of the Johns Hopkins University*, pp. 1–76, Pls. I–VIII. Baltimore, January, 1891.

42. MÜLLER, FRITZ. Palæmon Potiuna. Ein Beispeil abgekürzter Verwandlung. *Zool. Anz.*, No. 52, pp. 152–157. 1880.

43. ———. Berichtigung, die Verwandlung des Palæmon Potiuna betreffend. *Zool. Anz.*, No. 55, p. 233. 1880.

44. NUSBAUM, JOSEPH. L'Embryologie d'Oniscus murarius. *Zool. Anz.*, No. 228, pp. 455–458. 1886.

45. ———. L'Embryologie de Mysis Charmeleo. *Arch. de Zool. Expér. et Génerale*, 2d Ser., T. 15, Nos. 1–2, pp. 123–202, Pls. I–XII. 1887.

46. PACKARD, A. S. Notes on the Early Larval Stages of the Fiddler Crab and of *Alpheus*. *Amer. Naturalist*, Vol. XV, pp. 784–789, Figs. 1881.

47. PARKER, G. H. The Histology and Development of the Eye in the Lobster. *Bull. Mus. Comp. Zool.*, Vol. XX, No. 1, pp. 1–62, 4 Pls. 1890.

48. ———. The Compound Eye in Crustaceans. *Bull. Mus. Comp. Zool.*, Vol. XXI, No. 2, pp. 45–140, 10 Pls. 1891.

49. PATTEN, WILLIAM. The Development of Phryganids, with a Preliminary Note on the Development of Blatta Germanica. *Quart. Journ. Micros. Sci.*, Vol. XXIV, New Ser., pp. 549–602, Pls. XXXVI A, B, C. 1884.

50. ———. Eyes of Molluscs and Arthropods. *Mittheil. Zool. Station zu Neapel*, B. VI, H. IV, pp. 542–756, Taf. 28–32. 1886.

51. ———. Studies on the Eyes of Arthropods. I. Development of the Eyes of Vespa, with Observations on the Ocelli of some Insects. *Journ. of Morphology*, Vol. I, pp. 193–227, 1 Pl. 1887.

52. RATHKE, HEINRICH. Untersuchungen über die Bildung und Entwickelung des Flusskrebses. pp. 1–97, 5 Pls. Leipzig, 1829.

53. ———. Zur Entwickelungsgeschichte der Dekapoden. *Archiv. f. Naturgesch.*, B. VI, pp. 241–249. 1840.

54. REICHENBACH, HEINRICH. Studien zur Entwicklungsgeschichte des Flusskrebses. *Abhandl. Senckenberg. Naturforsch. Gesellsch.*, B. 14, pp. 1–137+2, Taf. I–XIV, I*a*–IV*a*, IV*b*. Frankfort, 1886.

55. RYDER, J. A. The Metamorphosis of the American Lobster, Homarus americanus, H. Milne Edwards. *Amer. Naturalist*, Vol. XX, pp. 739–742.

56. SCHIMKEWITSCH, WLADIMIR. Einige Bemerkungen über die Entwicklungsgeschichte des Flusskrebses. *Zool. Anz.*, No. 195, pp. 303–304. 1885.

57. SHELDON, LILIAN. Ovum in the Cape and New Zealand Peripatus. *Quart. Journ. Micros. Sci.*, Vol. XXX, New Ser., pp. 1–29, Pls. I–III.

58. SMITH, SIDNEY I. The Early Stages of the American Lobster (*Homarus americanus*—Edwards). Trans. Conn. Acad., Vol. II, Pt. 2, pp. 351–381, Pls. XIV–XVIII, + Figs. 1–4. 1873. Earlier papers in *Am. Journ. Sci. and Arts*, 3d Ser., Vol. III, pp. 401–406, 1 Pl., June, 1872, and in *Rept. U. S. Fish Comm. of Fish and Fisheries* on the Condition of the Sea Fisheries of the Southern Coast of New England in 1871 and 1872, pp. 522–537. Washington, 1873.

59. ———. Report on the Decapod Crustacea of the Albatross Dredgings off the East Coast of the United States during the Summer and Autumn of 1884. *Ann. Rept. of Comm. of Fish and Fisheries* for 1885, pp. 1–101, Pls. I–XX. Washington, 1886.

60. VAN BENEDEN, ÉDOUARD, and BESSELS, ÉMILE. Mémoire sur la Formation du Blastoderm chez les Amphipodes, les Lernéens et les Copépodes. Mém. Cour. et Mém. de Sav. Étr. publ. par l'Acad. Roy de Belgique, T. XXXIV, pp. 1–59, Pls. I–V. 1870.

61. VIALLANES, H. Études histologiques et organologiques sur les centres nerveux et les organes des sens des animaux articulés. Premier mémoire. Le ganglion optique de la langouste (*Palinurus vulgaris*). Ann. des Sci. Nat. Zool. et Paléontol.

62. ——. Études histologiques et organologiques sur les centres nerveux et les organes des sens des animaux articulés. Cinquième Mémoire. I. Le Cerveau du Criquet (*Œdipoda cœrulescens et Caloptenus italicus*). II. Comparaison du cerveau des crustacés et des insectes. III. Le cerveau et la morphologie du squelette céphalique. Ann. des Sci. Nat., Zool. et Paléontol., T. IV., Nos. 1–3, VII Ser., pp. 1–120, Pls. 1–6. 1887.

63. WATASE, S. On the Morphology of the Compound Eyes of Arthropods. *Studies fr. Biol. Lab'y of the Johns Hopkins University*, Vol. IV, pp. 287–334, 7 Pls. 1890.

64. WALDEYER, W. Eierstock und Ei.

65. WILSON, HENRY V. On the Breeding Seasons of Marine Animals in the Bahamas. *Johns Hopkins University Circulars*, Vol. VIII, No. 70, p. 38.

66. WOOD-MASON. Stridulating Crustacea. Remarks of Mr. Wood-Mason at the November meeting of the Entomological Society of London. *Nature*, Vol. XVIII, p. 53. 1878.

67. WHEELER, WILLIAM M. The Embryology of Blatta Germanica and Doryphora Decemlineata. *Am. Journ. Morphology*, Vol. III, No. 2, pp. 291–386, Pls. XV–XXI. 1889.

APPENDIX I.

THE LIFE HISTORY OF STENOPUS.

Since this paper was written Chun has described (Die pelagische Thierwelt in grösseren Meerestiefen, Bibliotheca Zoologica, I, 1888) a small transparent crustacean which he calls *Meiersia clavigna*. It occurs at the surface and also at various depths down to 600 M. A comparison of his description and figure (Taf. IV, Fig. 6) with the Stenopus larva shown in Pls. IX and X of this memoir shows that Chun's *Meiersia clavigna* is undoubtedly a Stenopus larva, a little older than the one shown in Pl. X. (W. K. B.)

It is suggested at the bottom of page 340 that the cement by which the eggs are fastened to the abdomen may possibly come from the oviducts. According to recent observations of Cano (*Mittheil Zool. Stat. Neapol.*, IX, 1891; abstract in *Journ. Roy. Mic. Soc.*, No. 83, 1891) this is derived from cement glands situated in Stenopus under the epidermis of the pleopods. It is thought by Cano that these glands, to which the secondary egg membrane is due, are modified glands of the appendages, and that the cement substance may serve as the medium through which spermatozoa reach the ova. In order to reach the eggs the sperm cells probably pass through pores in the chorion.

This paper was written in the summer of 1888, before I had seen the report of Spence Bate on the *Challenger* Macrura (Report on the Crustacea Macrura dredged by H. M. S. *Challenger* during the years 1873–'76, Zoology, Vol. XXIV, p. 209, Pl. XXX, 1888). The *Challenger* brought home only two specimens of *Stenopus hispidus*, one from Kandavu, Fiji Islands, and one from Bermuda. Spence Bate says that Stenopus has been "chiefly recorded from the eastern seas and the shores of India by Desmarest, Milne-Edwards, and Sir Walter Eliott; from Japan by de Haan." It has been thought that *Squilla greenlandica* of Seba, which appears under several names, may be the same as *Stenopus hispidus*. "The genus," says Bate, "thus appears to inhabit regions so widely apart as Greenland in the north, the Bermudas and Mediterranean in the west, and the southern coasts of India and the Fiji Islands in the east. It has been found in the cold waters of the Arctic regions as well as in the warm shallow waters of the tropics, but, despite this cosmopolitan range, it has not been recorded as having existed in any geological formation."

While the conclusion that the Arctic form is a *Stenopus* may be correct, it seems highly improbable that it is specifically related to *Stenopus hispidus*. There is no evidence at least to show that this is the case.

Bate figures a late egg embryo of Stenopus (Fig. 40, p. 212), and erroneously concludes that the animal has a short metamorphosis and that it hatches as a "Megalopa." He also gives a drawing (Pl. XXIX, Fig. 2, v.) of the first larva of *Spongiola venusta* (a prawn which is placed by Bate in the family Stenopidæ). This is clearly not a zoea, but a *protozoea*, as is better shown by the sketch of the recently hatched larva (Fig. 42, p. 216) by von Willemoes Suhm, and the strong resemblance which it bears to the protozoea of *Stenopus hispidus* is very striking (compare with Pl. VII, Fig. 11, of this paper).

According to Bate the branchial formula of Stenopus was first elucidated by Huxley in his memoir on the classification of crayfishes (Proc. Zool. Soc., London, 1878). There are *six* pleurobranchiæ; *eleven* arthrobranchiæ, five of which are anterior and six posterior; *one* podobranchia, and *six* mastigobranchiæ, of which the first is the only efficient appendage.

Spence Bate states that after careful comparisons he failed to find specific differences between specimens from the Eastern and Western Hemispheres.

ERRATA.

As numerous errors have unavoidably occurred in this paper, I will correct the more important of them.

Page 341, line 8, for "Pl. VII" read Pl. X.

Page 341, line 13, for "Lesneur" read Lesueur.

Page 343, line 2, for "cells have spread more rapidly at a given point on the egg" read cells have increased more rapidly over a given area of the egg.

Page 343, over table for "Temperature 80° F.," read Temperature of air, 80° F.

Page 344, lines 11, 16, 31, 32, and 47, for "Fig. 10" read Fig. 11.

Page 344, line 18, for "largely developed" read highly developed.

Page 345, line 20, for "Fig. 10" read Fig. 11.

Page 345, line 30, for "Fig. 11" read Fig. 10.

Page 345, line 38, for "the first and second maxillipeds" read the second and third maxillipeds.

Page 346, line 31, for "larger than telson" read longer than telson.

Page 347, line 16, for "XII and Fig. 40" read XIII and Fig. 39.

Page 347, line 29, for "and 38" read and 39.

Page 347, lines 37 and 41, for "Pl. XI" read Pl. XII.

Page 347, line 40, for "Figs. 43, 45" read Figs. 43, 44.

Page 347, line 47, for "Fig. 47" read Fig. 46.

Page 348, line 15, omit "errinem.....larve."

Page 348, for lines 32–34 read: Body nearly cylindrical; tergal surface covered with spines. Carapace with prominent laterally compressed rostrum and distinct cervical and branchio-cardiac grooves. Outer antennæ with long bristle-bordered scale bent under the inner antennæ toward the middle line. Second maxillipeds with setigerous lamina, attached to endopodite.

Page 348, line 46, for "a marked transverse fossa" read a marked cervical groove.

Page 348, last line, for "transverse furrow" read cervical or mandibular groove.

Page 349, line 17, for "Fig. 40" read Fig. 39.

Page 349, line 21, for "their inner borders which meet in the middle line" read the inner borders of the exopodites which meet in front.

Page 349, line 23, for "Fig. 39" read Fig. 38.

Page 349, line 25, for "Fig. 38" read Fig. 36.

Page 349, line 39, for "Fig. 48" read Fig. 45.

Page 349, seventh line from bottom, for "the great chelæ" read bearing the great chelæ.

Page 350, first line, for "Fig. 48" read Fig. 47.

Page 350, first and second lines, for "bearing a shorter proximal one below" read bearing a longer tooth and a shorter proximal one below.

Page 350, line 9, for "Fig. 41" read Fig. 40.

Page 350, table, tenth line from bottom, for "Length of chela" read Length of chela of same.

Page 352, line 10, for "hartschälig" read hertschalig.

Page 352, tenth line from bottom, for "Crustaces, Arachnidses" read Crustacés, Arachnides.

APPENDIX II.

PARASITIC FUNGUS IN THE EGG EMBRYOS OF ALPHEUS SAULCYI.

The remarkable parasite of *Alpheus saulcyi*, to which allusion was made in Part First of the Memoir on the development of Alpheus, is illustrated in Fig. 199, Pl. LIII. Although a large number of egg-bearing females were examined and their eggs were sectioned, only a single female (a small specimen, probably var. *longicarpus*, obtained from the "loggerhead sponge" at Abaco) was found to be infested with this singular parasite. We may therefore regard it as very rare under these conditions.

The sections of these embryos were very kindly examined by Professors Joseph Leidy and W. G. Farlow. In reference to them Dr. Farlow writes as follows:

The parasite is certainly of great interest. I cannot find any description of it in botanical literature, although it appears to be a fungus belonging to Chytridiaceæ.

The fungus has no mycelium, but is composed of single cells of various sizes. In a section like that shown in Fig. 199 nearly one hundred large cells or cysts can be counted, and it is seen that the peripheral parts of the embryo are packed with them. These embryos were alive, although the embryonic cells were considerably altered from their normal condition, where they came in contact with the parasitic growths and showed traces of degeneration.

The parasitic bodies are mainly (1) large naked cysts or encysted cells, and (2) very small spore-like bodies. The naked cyst (*c. s.*, Fig. 199) is a thick shell which has collapsed and curled up with the escape of its contents. It is yellowish and is unaffected by staining reagents. The surface of the cyst is covered with very uniform, short projections or tubercles, which refract the light in a characteristic way.

Other encysted cells contain a protoplasmic reticulum (cs^1), and there are very similar but smaller bodies which are either naked or possess but a slight cuticular wall. These encysted bodies just described possibly represent zoosporangia, and give rise to the myriads of minute spores which occur in close relation with them. The spores (Fig. 199, *sp.*, represented by small black dots) are minute, oval, and highly refractive. In the eye and other organs certain nuclei take up the stain very eagerly and refuse to part with it. These are probably the nuclei of embryonic cells which have undergone modification. Occasionally one of the cysts appears black (cs^2), which is due mostly, if not wholly, to refraction.

According to Goebel, reproduction in the *Chytridieæ* is effected by means of swarm spores. Resting cells occur, which germinate and become sporangia, producing large numbers of swarm spores. Some forms, like Chytridium, have no mycelium. Its single cells, which live on or within the host plant, after reaching their full size become zoosporangia. These give rise to swarm spores, which are liberated into the water. The *Chytridieæ* are described as parasites on other aquatic plants, Fungi, Algæ, and Phanerogams.

According to De Bary resting spores are known to occur in certain species. These develop directly into sporangia or produce them after a short intermediate stage, and appear to resemble the sporangia in size and in possessing a warty cellulose coat.

APPENDIX III.

Some early abstracts of this work (Alpheus: A Study in the Development of Crustacea) were included in the Introduction published in the Johns Hopkins University Circulars, No. 97, April, 1892. The part relating to the embryology of Alpheus was here printed in its unrevised form, and differs materially from the results of later studies which are given in this memoir.

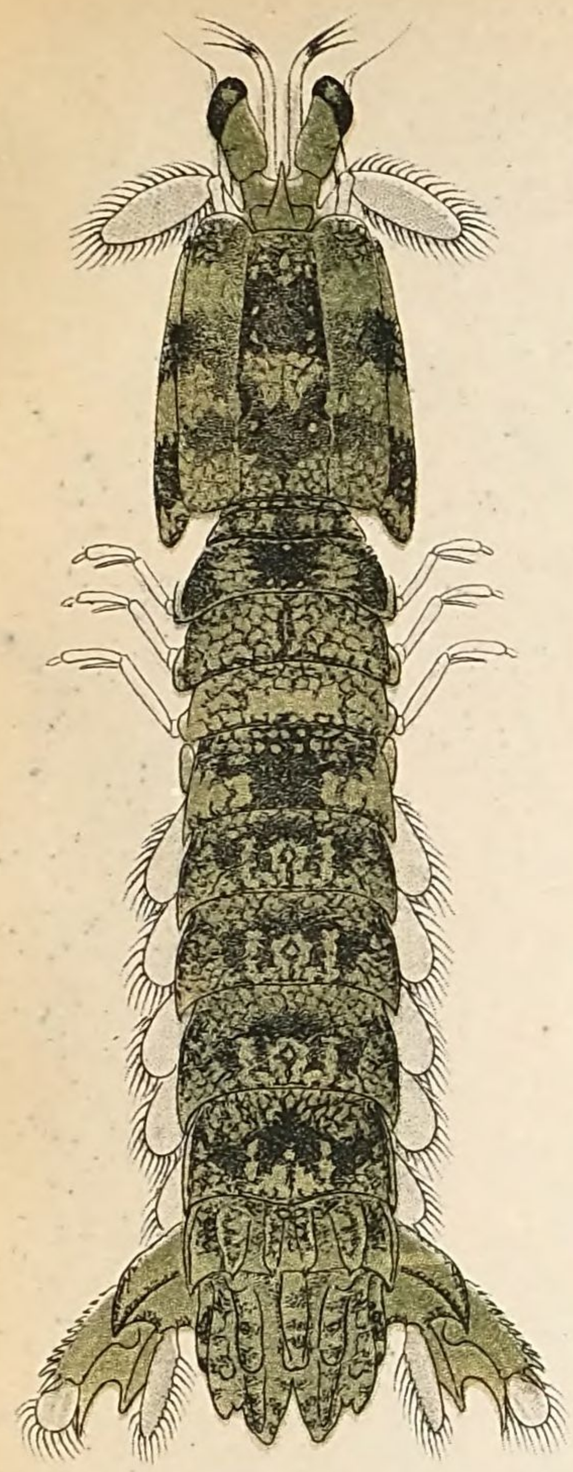
While this work was in press it was thought best to change the name Alpheus minus of Say to the correct form, *Alpheus minor*. As some of the pages were stereotyped before this correction was made, both forms of the name appear.

ADELBERT COLLEGE,
Cleveland, Ohio, May, 1892.

Plate I.

Alpheus minor, drawn from life by W. K. Brooks. (Enlarged eight diameters.)

Dorsal view of a specimen of the gray variety of *Gonodactylus chiragra*, twice natural size.



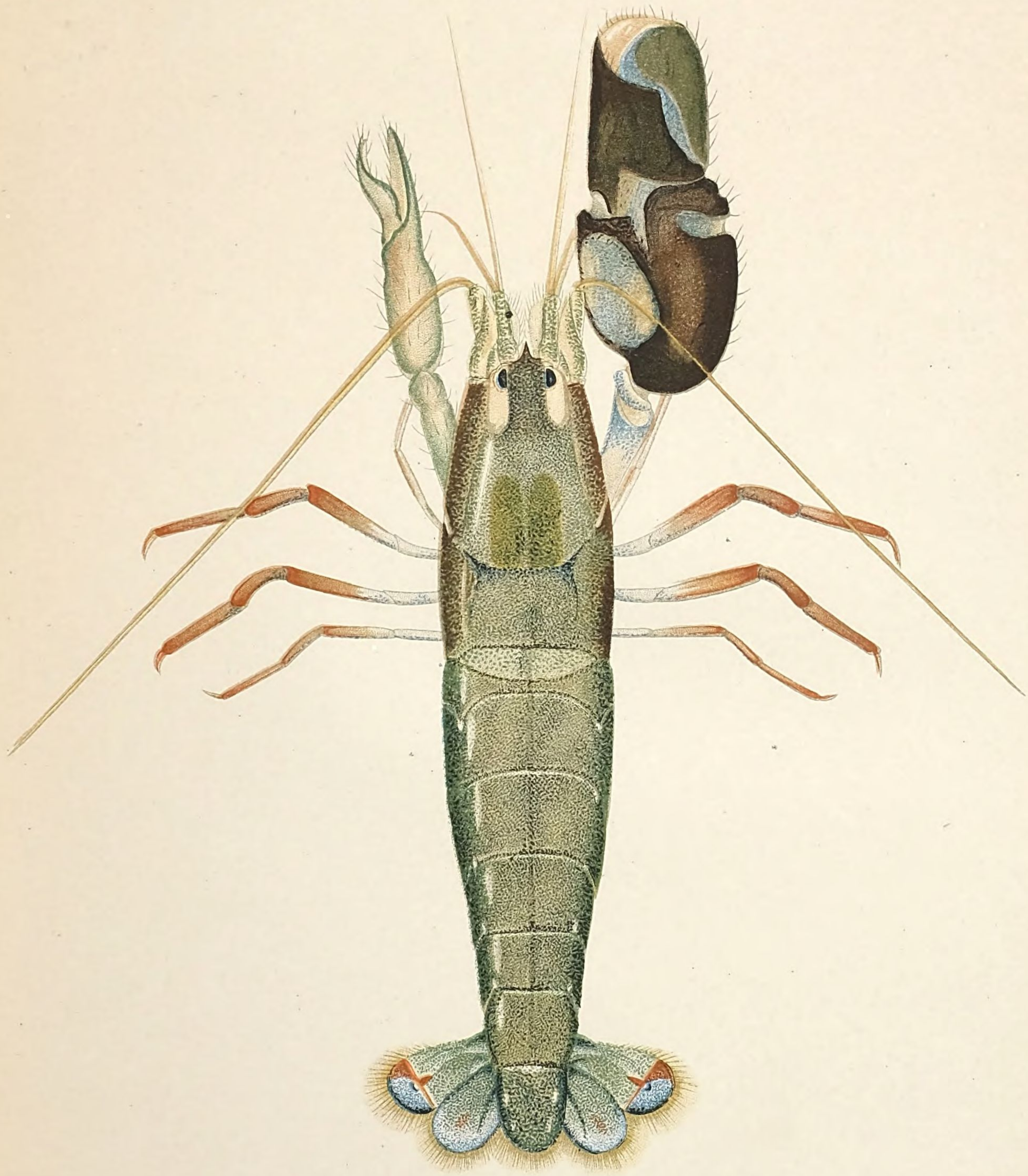
W. K. Brooks, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS MINUS AND GONODACTYLUS CHIRAGRA.

Plate II.

Alpheus heterochelis, drawn from life by W. K. Brooks. (Four times life-size.)



W. K. Brooks, del.

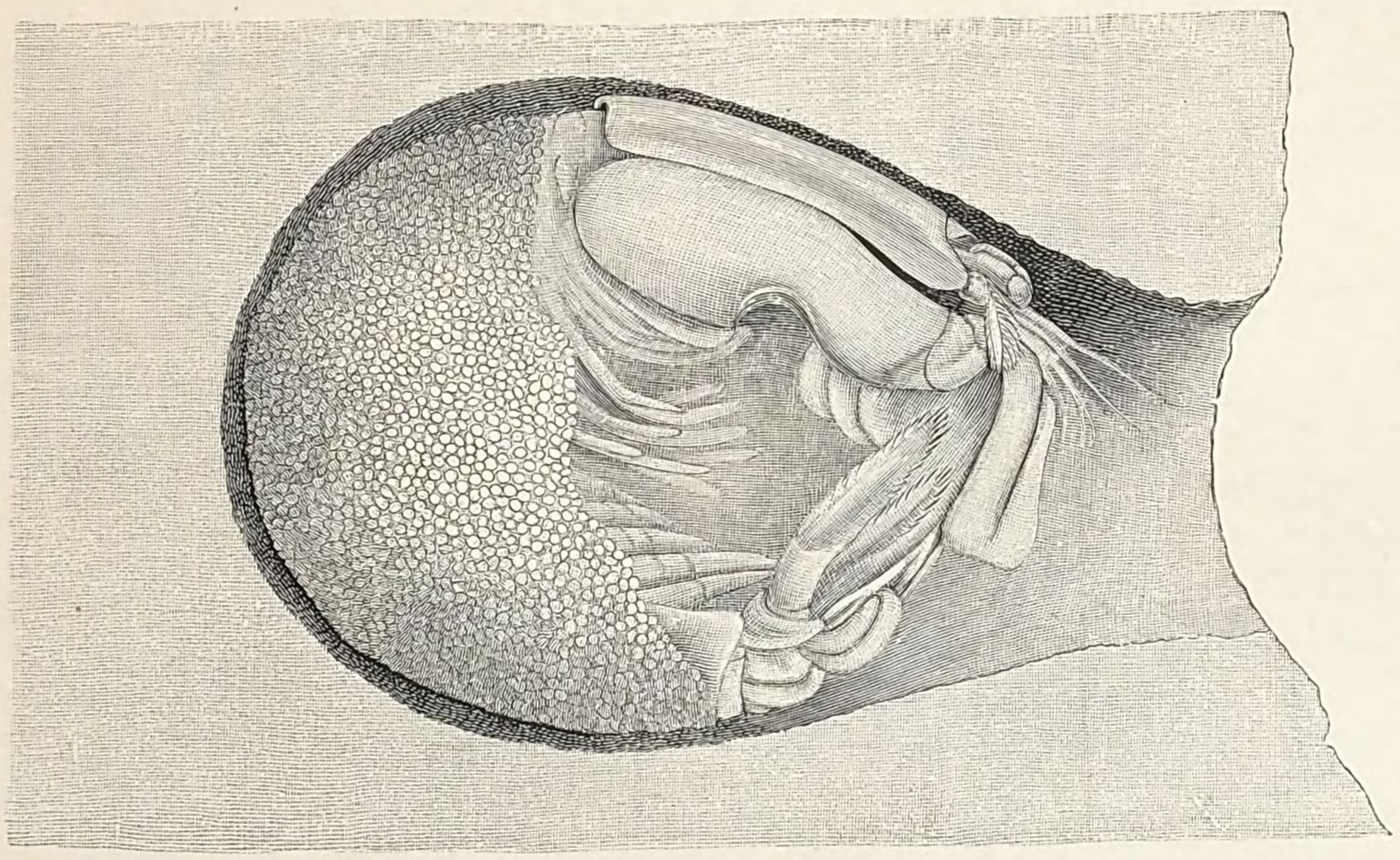
Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS HETEROCHELIS.

Plate III.

Gonodactylus chiragra, drawn by W. K. Brooks.

Adult female of the green variety, in her burrow, with eggs, twice natural size.



W. K. Brooks, del.

GONODACTYLUS CHIRAGRA.

Plate IV.

Adult male and female of *Alpheus saulcyi*, var. *brevicarpus*, from Nassau, New Providence.

Fig. 1. Lateral view of female from green sponge. $\times 3\frac{1}{2}$.

Fig. 2. Dorsal view of the same. $\times 3\frac{1}{2}$. Parts only of the ovaries are visible in Fig. 2, while the eggs, which greatly distend the abdomen laterally, show plainly between the bases of the swimmerets. In Fig. 1 the small chela is bent downward, the position in which it is usually carried. In Fig. 2 the chelæ are represented in the attitude of defense. The dactyle of the left "hand," or large chela, is raised preparatory to striking.

Fig. 3. Small male. L = $\frac{10}{16}$ in. $\times 7\frac{1}{2}$. Drawn under slight pressure, owing to which the antennal spines and the antennular exopodites have assumed an unnatural position. The posterior margin of the carapace is more correctly represented in Fig. 1.

1.

2.

3.

F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS SAULCYI, VAR. BREVICARPUS.

Plate V.

Dorsal view of the adult male *Stenopus hispidus*. Nassau, N. P., June, 1887. L = $1\frac{3}{4}$ in. L. first antenna, exopodite—$3\frac{7}{8}$ in., endopodite—$3\frac{3}{8}$ in. L. second antenna = $4\frac{11}{16}$ in. $\times 1\frac{3}{4}$.

Excepting the brilliant pigment bands the body and appendages are nearly white, and could be better represented against a black background. The arching flagella of the antennæ are greatly foreshortened, and the spines and setæ are of necessity unduly emphasized in a pen and ink drawing.

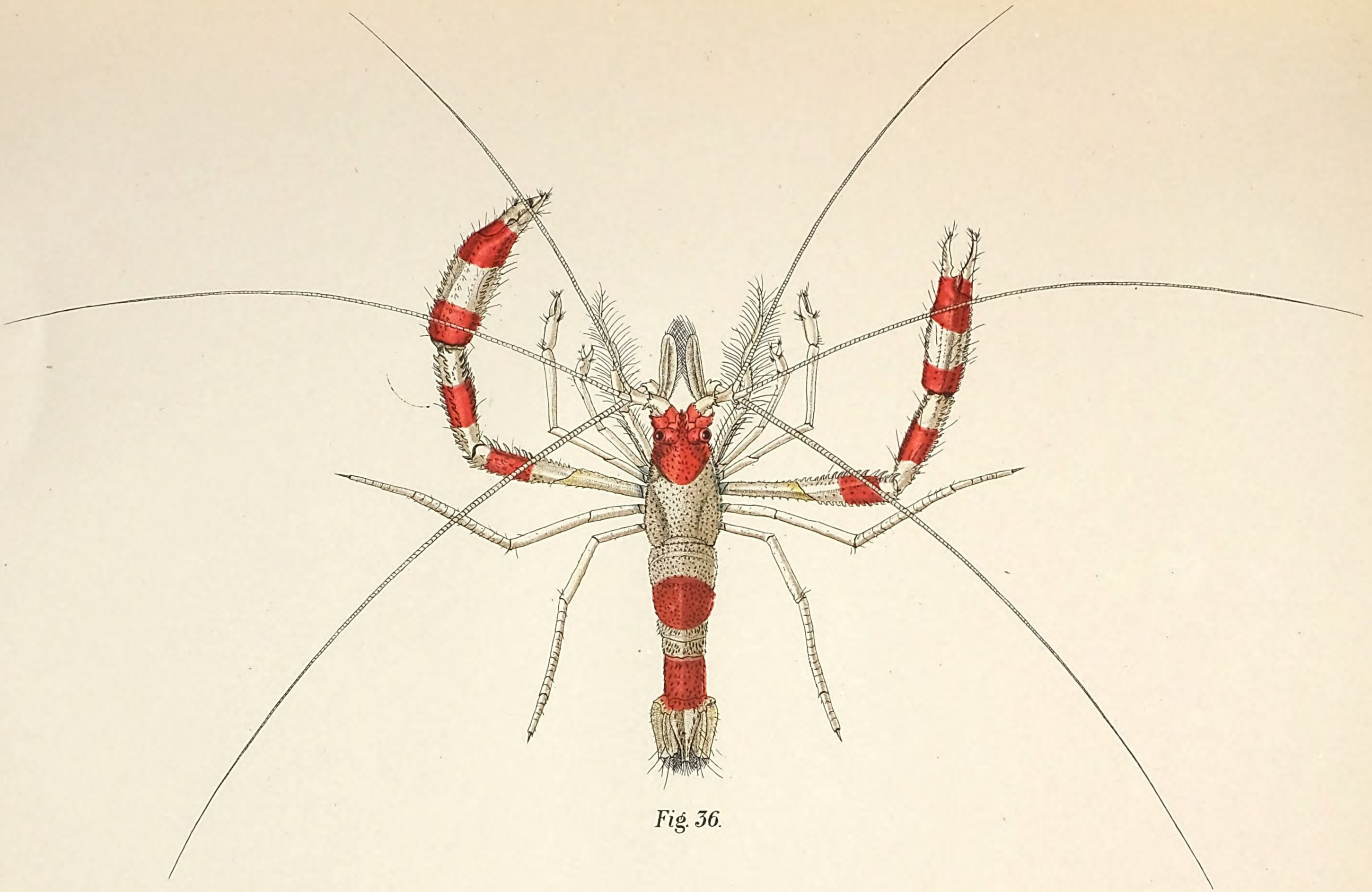


Fig. 36.

F. H. Herrick, del.

STENOPUS HISPIDUS.

Sackett & Wilhelms Lithographing Co. New York

Plate VI.

Fig. 1. Part of section of egg, showing the male pronucleus. The female pronucleus lies nearer the center of the egg, is less regular in outline and has less perinuclear protoplasm. A single polar body (not represented) is seen in this section. It lies close to the surface of the egg, beneath the membranes, not far from the male pronucleus. It appears as a small mass of chromatin, which stains quite as intensely as the nuclei. Egg about 6 hours old. ×276.

Fig. 2. Section of egg with four nuclei, none of which are at the surface. ×152.

Fig. 3. Part of same section, showing the nucleus and surrounding protoplasm and yolk. ×276.

Fig. 4. Lateral section, cutting yolk segment on a level with the disk-shaped nucleus. Compare Fig. 5 a. Eight-cell stage. Age about 12 hours. ×276.

Fig. 5. Section through egg in eight-cell stage. Compare Fig. 6. Age about 15 hours. ×152.

Fig. 6. Surface view of egg in the third segmentation or eight-cell stage. The egg membranes have been removed. The nuclei lie at a deeper level than they appear in the drawing. Compare Fig. 5. ×78.

Fig. 7. Section of egg in the fourth segmentation stage. Sixteen cells. ×152.

Fig. 8. Fifth segmentation stage. Age, 19 hours. Cells not yet at surface. ×152.

Fig. 9. Invagination stage. A solid ingrowth of blastodermic cells has taken place at *Ig*, where a slight pit is formed. The section cuts obliquely through the invaginate cells. ×152.

REFERENCE LETTERS.

a, perinuclear protoplasm.
Ch, chitinous egg envelopes (removed, except in Fig. 5).
Ep, ectoblastic cell.
Ig, shallow pit of invagination.
y. c., yolk spherule.

Fig.1

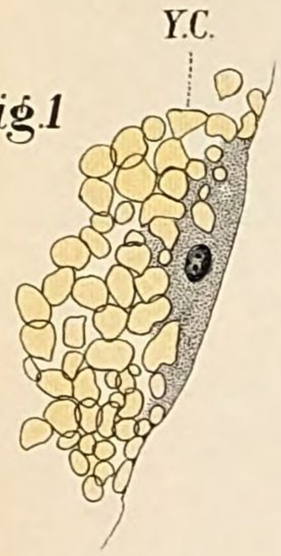


Fig.2.

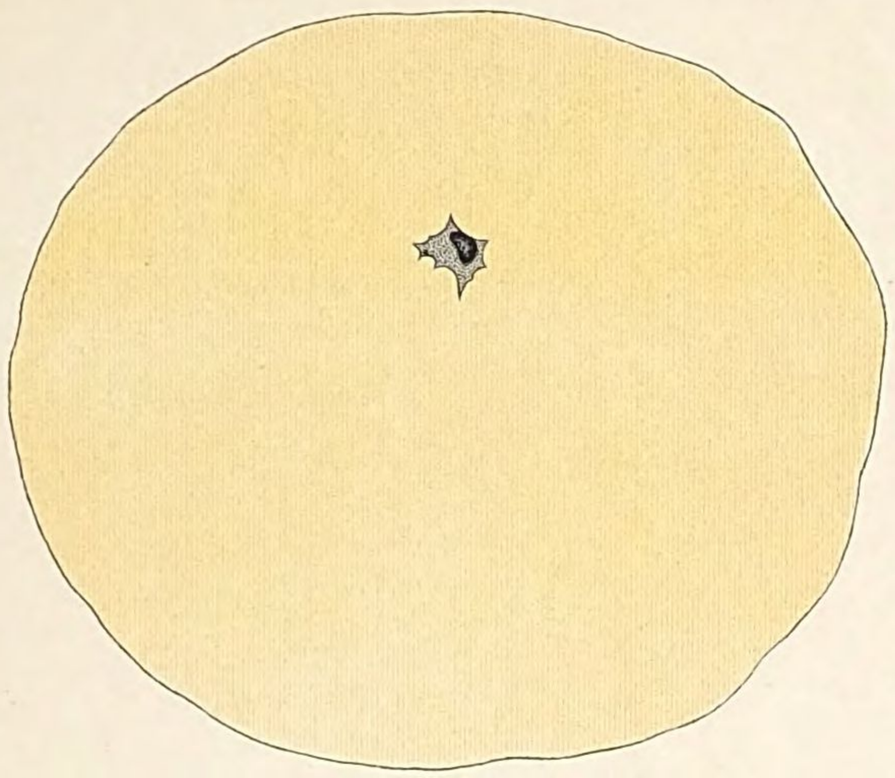


Fig.3.

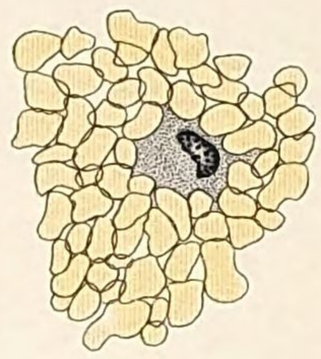


Fig.4

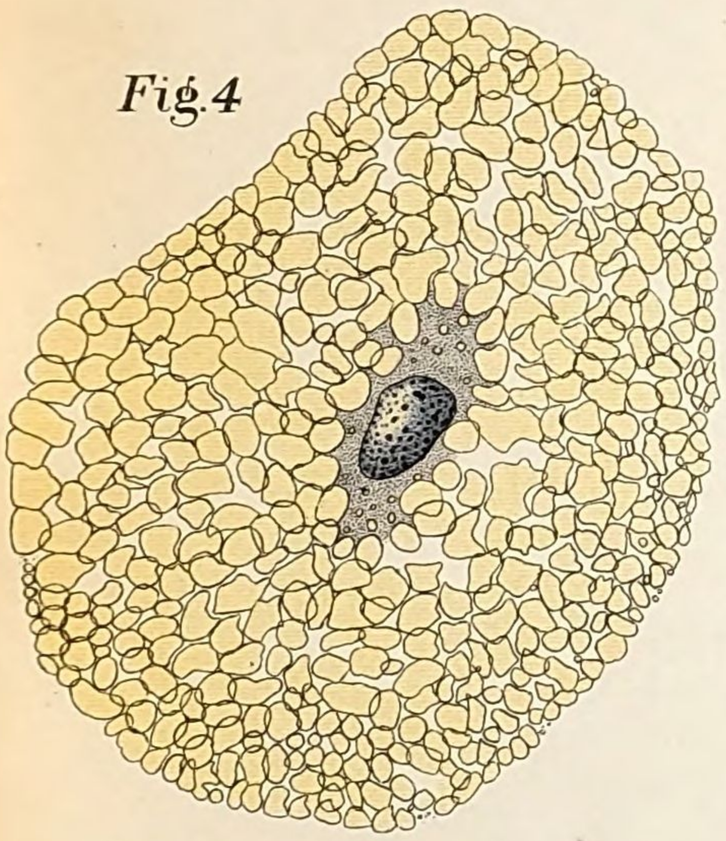


Fig.5.

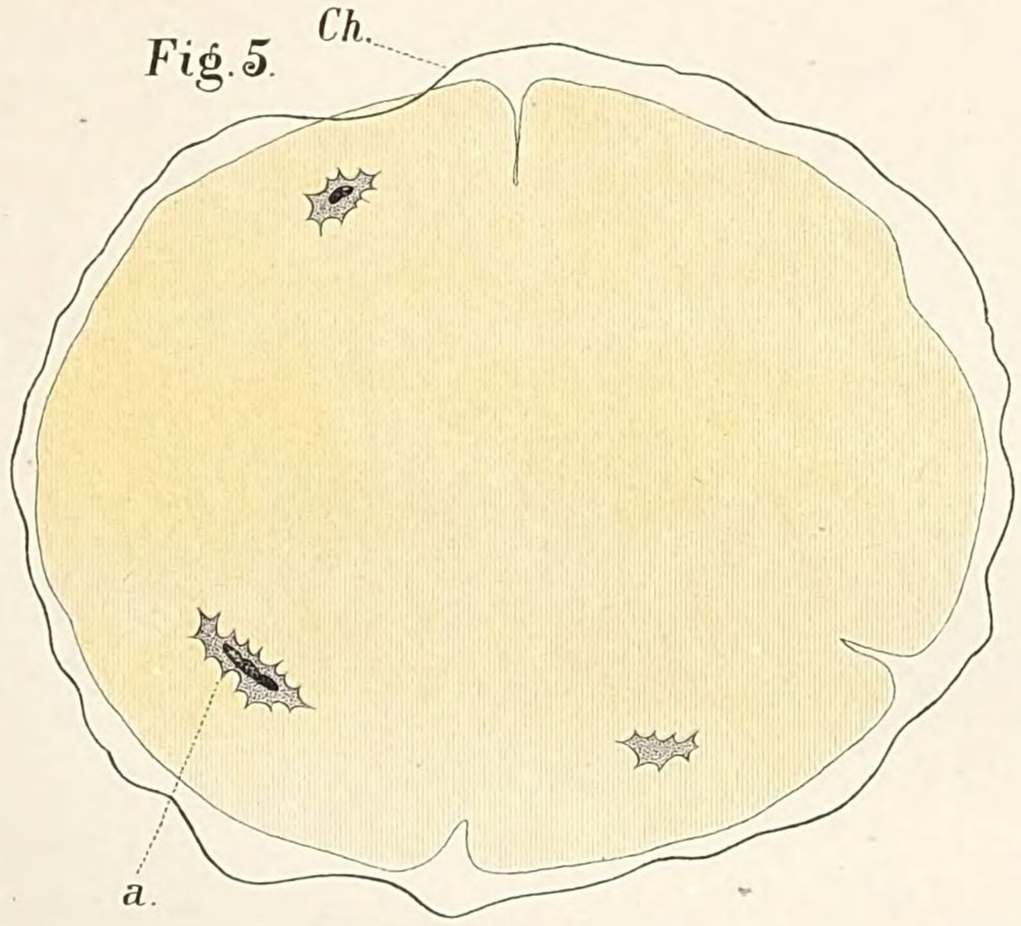


Fig.6.

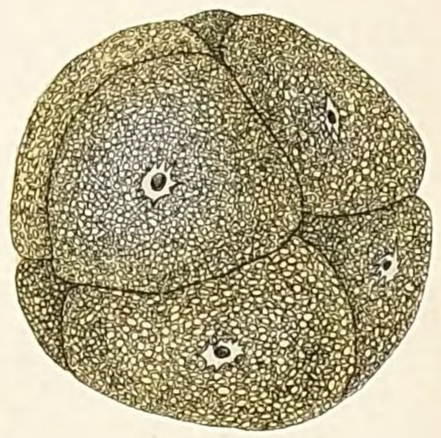


Fig.7.

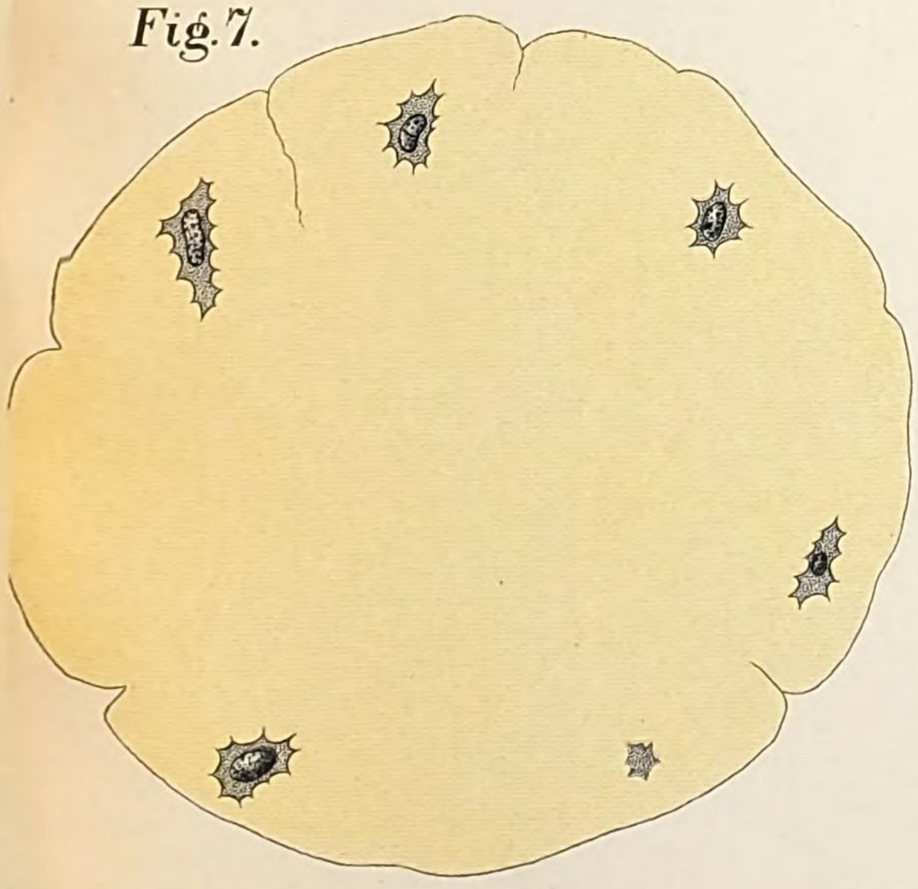


Fig.8.

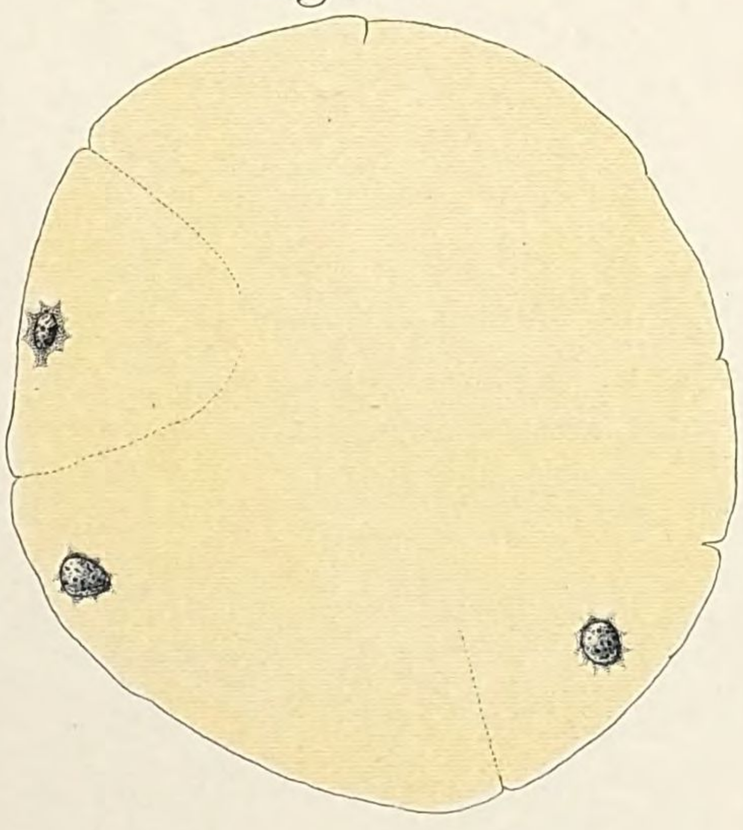
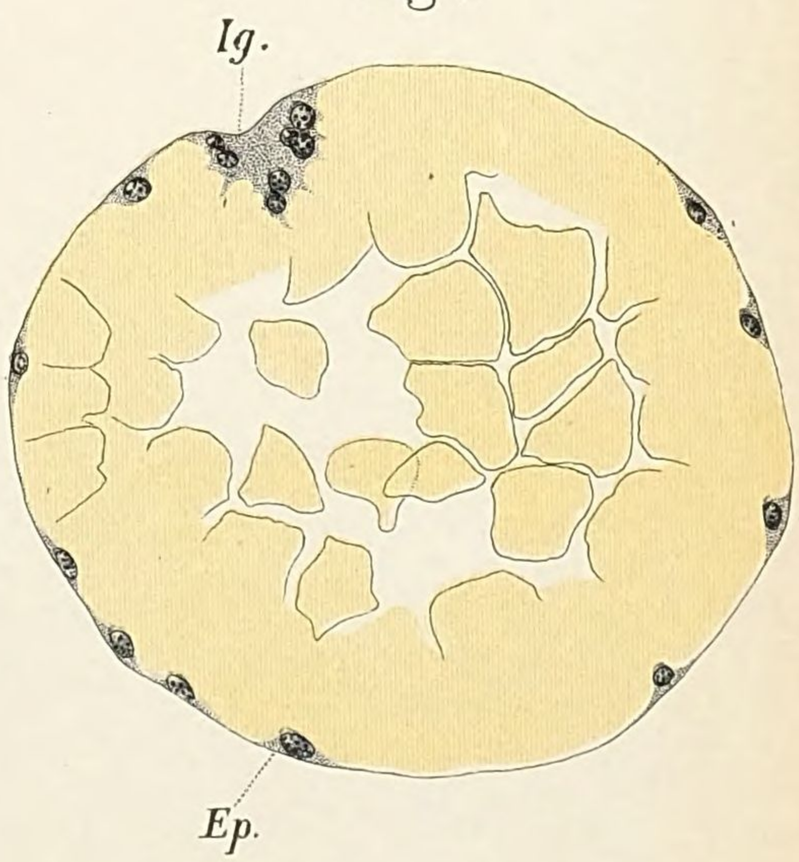


Fig.9.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

STENOPUS HISPIDUS.

Plate VII.

Fig. 10. Left second maxilla of larva at the point of hatching, before the first molt. ×276. Compare with Figs. 25 and 21.

Fig. 11. First swimming larva, after the first molt, seen from below. Pigment cells, brown. L = $\frac{16}{100}$ in. (measured from tip of rostrum to median notch of telson). Length of rostrum = $\frac{6}{100}$ in. ×70.

Fig. 12. Right first maxilla of first larva, seen from the outer side. Setæ rudimentary. Compare Figs. 19, 25. ×276.

Fig. 13. Telson of larva before first molt, seen from below. Compare Fig. 11. The setæ are invaginated and covered with a loose cuticle. ×276.

Fig. 14. Right first maxilliped of larva on the point of hatching, seen from the outer side. Setæ invaginated. Compare Figs. 22, 25. ×276.

Fig. 15. Labrum and right mandible of larva, seen from above. ×276.

Fig. 16. Right third maxilliped of larva on the point of hatching, seen from the outer side. Compare Fig. 25. ×276.

REFERENCE LETTERS.

a, outermost spine in telson of larva at the point of hatching.
d, equivalent of *a* in first locomotory larva.
Lb, labrum.

Fig. 10.

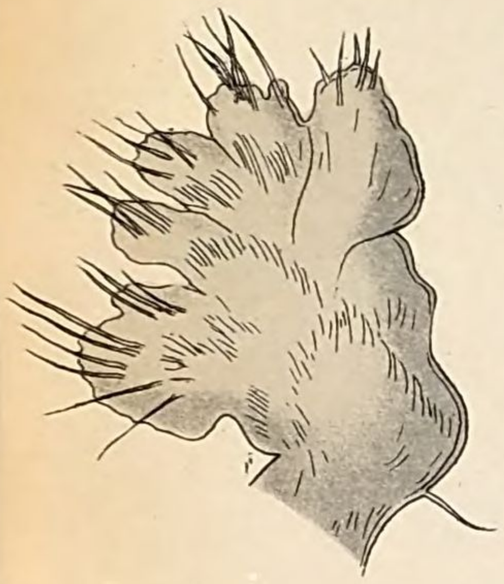


Fig. 11.

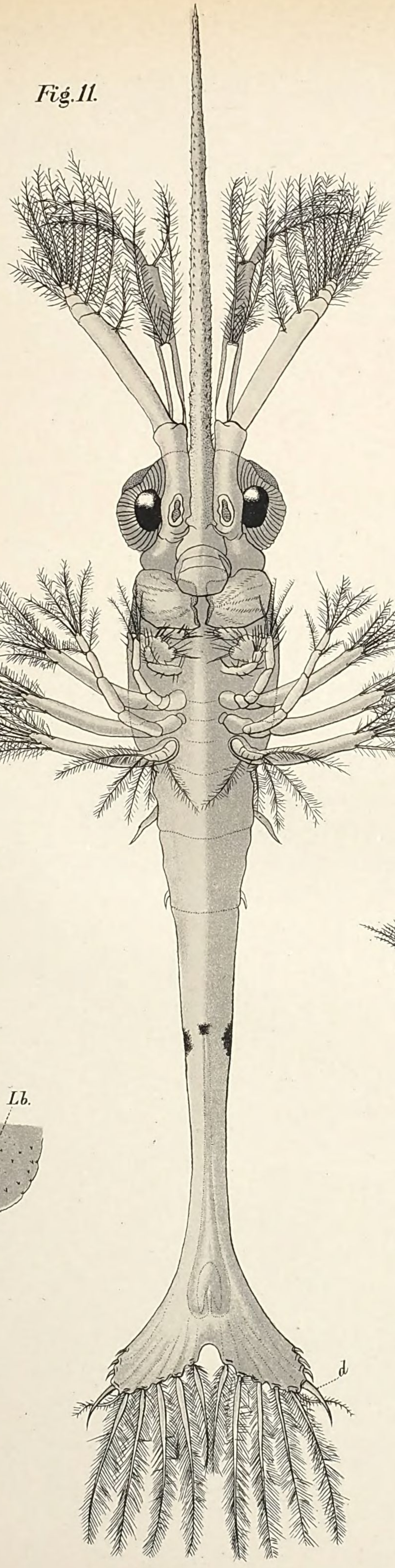


Fig. 12.

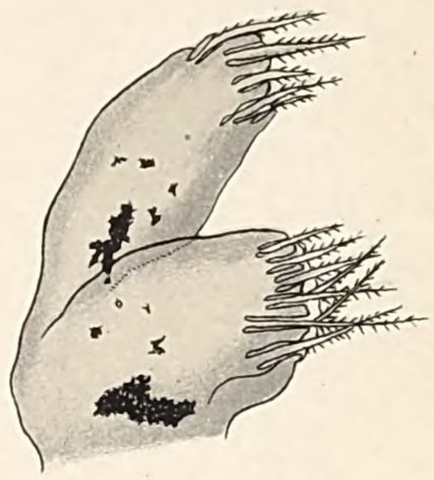


Fig. 13.

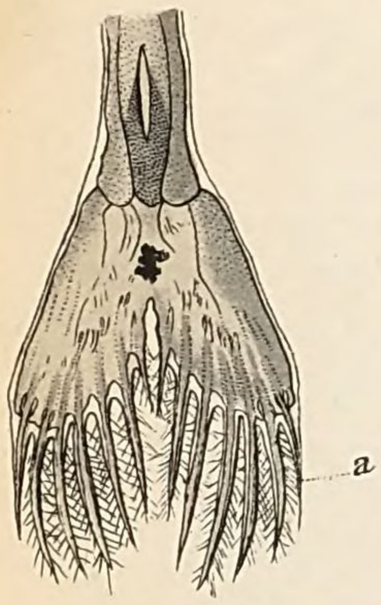


Fig. 14.

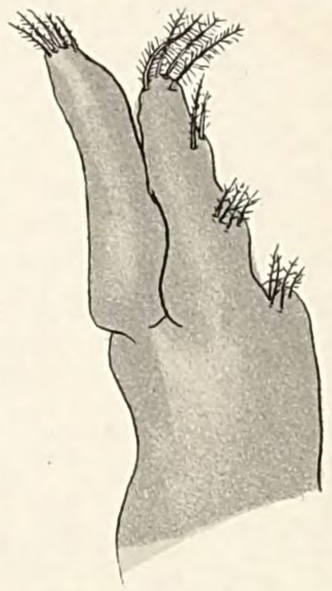


Fig. 15.

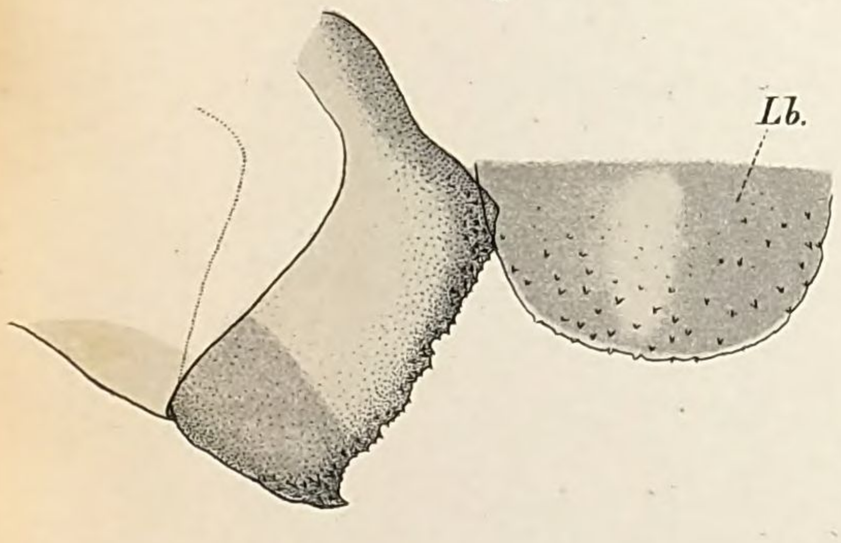
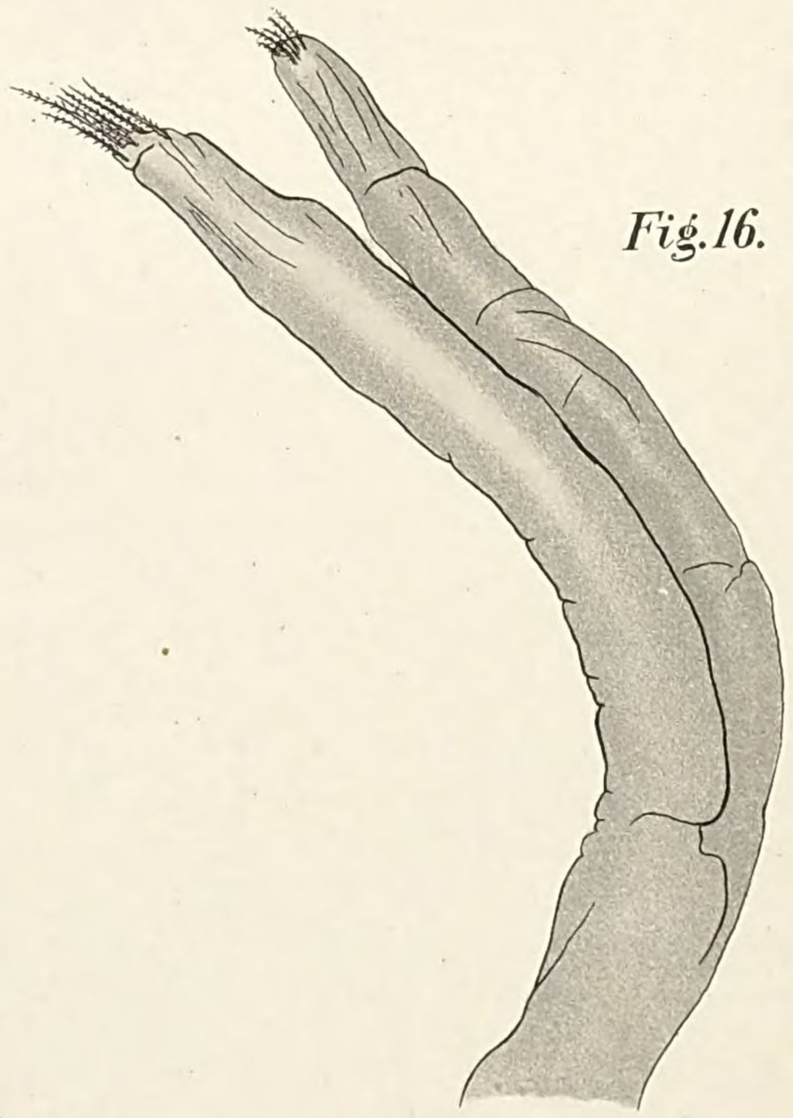


Fig. 16.



F.H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

STENOPUS HISPIDUS.

Plate VIII.

Fig. 17. Second larva after second molt. L=$\frac{21}{100}$ in. ×70.
Fig. 18. Left mandible, outer side, of second larva. ×276.
Fig. 19. First maxilla of second larva. ×276.
Fig. 20. Telson of second larva, seen from below. ×70.
Fig. 21. Left second maxilla of second larva, seen from the outer side. ×276.
Fig. 22. Right first maxilliped of second larva, seen from the outer side. ×276.

REFERENCE LETTERS.

g g, gastric gland.
. . . . the dotted line in Fig. 20 points to the outer spine, the equivalent of *d*, Fig. 11.

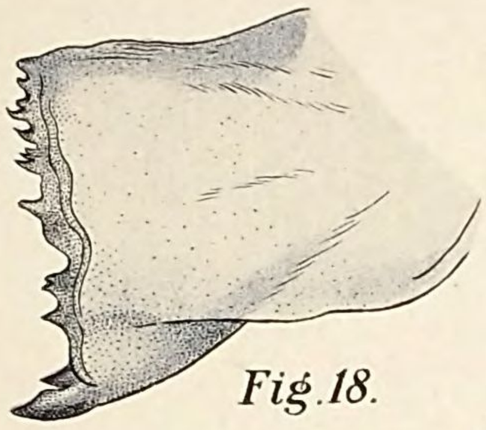


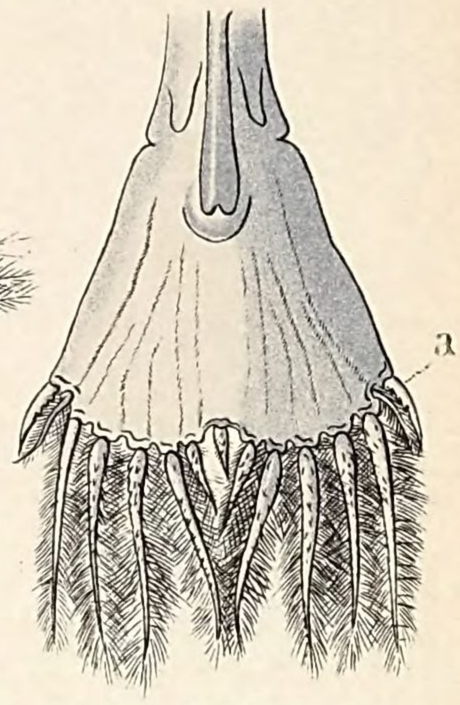
Fig. 18.



Fig. 19.

gg.

Fig. 17.



a

Fig. 20.

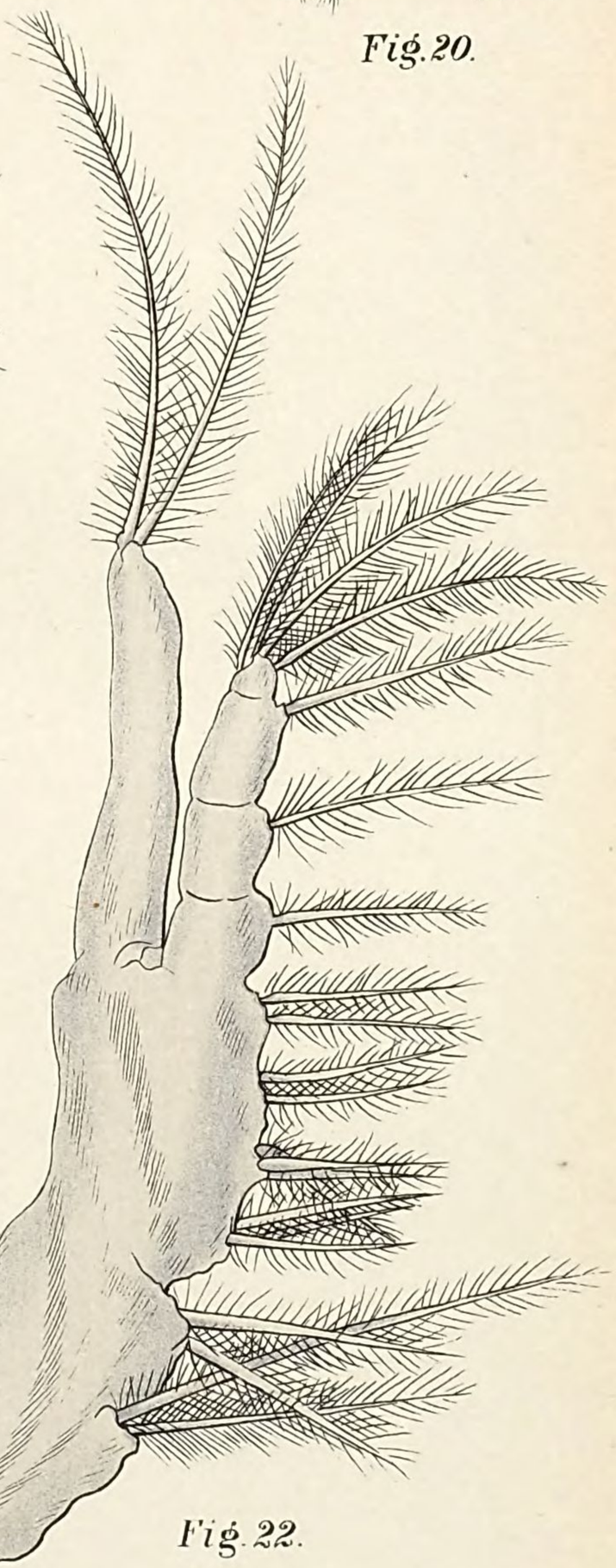


Fig. 22.

Fig. 21.

F. H. Herrick, del.

STENOPUS HISPIDUS.

Plate IX.

Advanced pelagic larva of Stenopus hispidus, from Beaufort, North Carolina, drawn from life by W. K. Brooks.

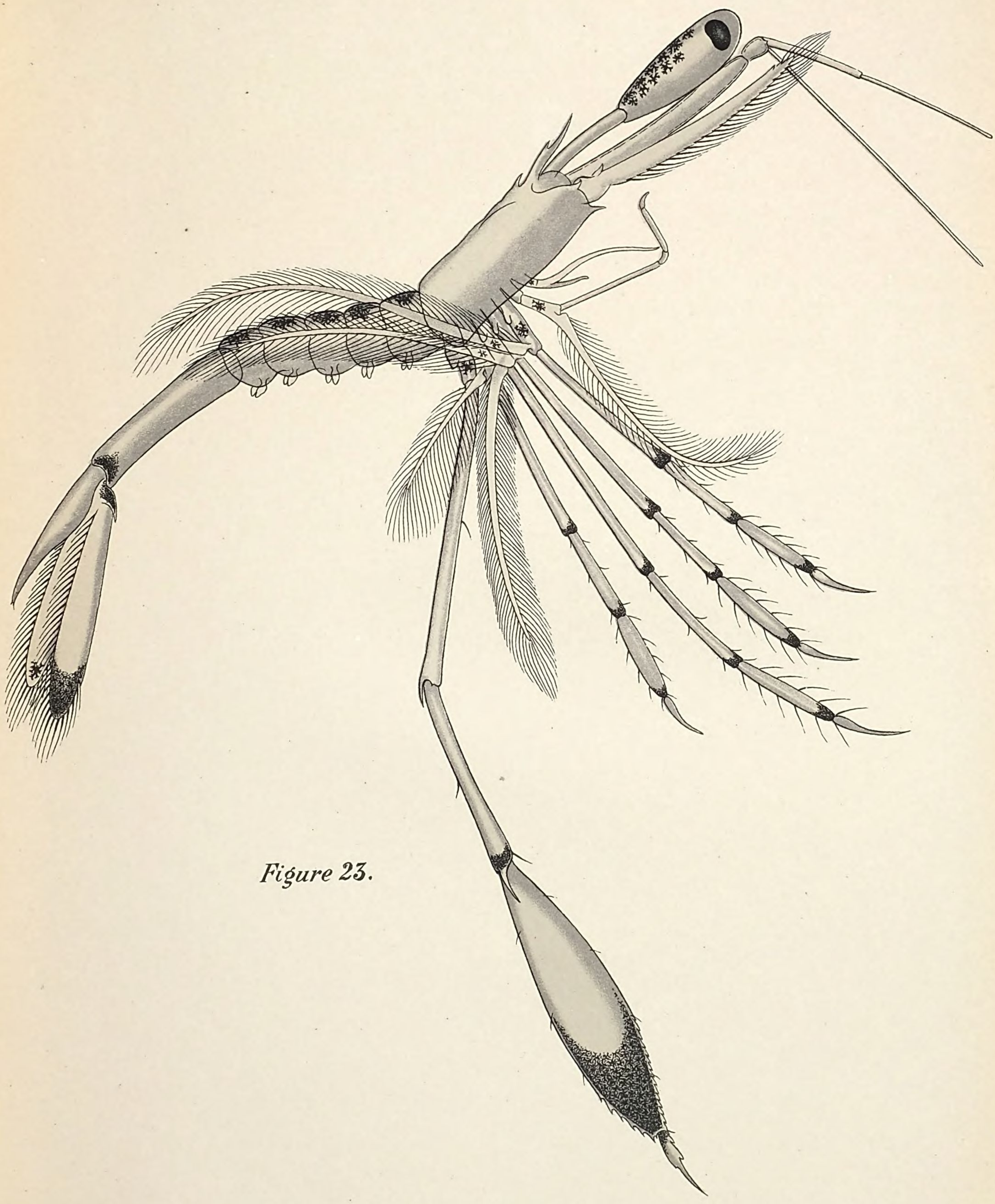


Figure 23.

W. K. Brooks, del.

Sackett & Wilhelms Lithographing Co. New York.

STENOPUS

Plate X.

Dorsal view of a larva like the one shown in Plate IX, drawn from life by W. K. Brooks.

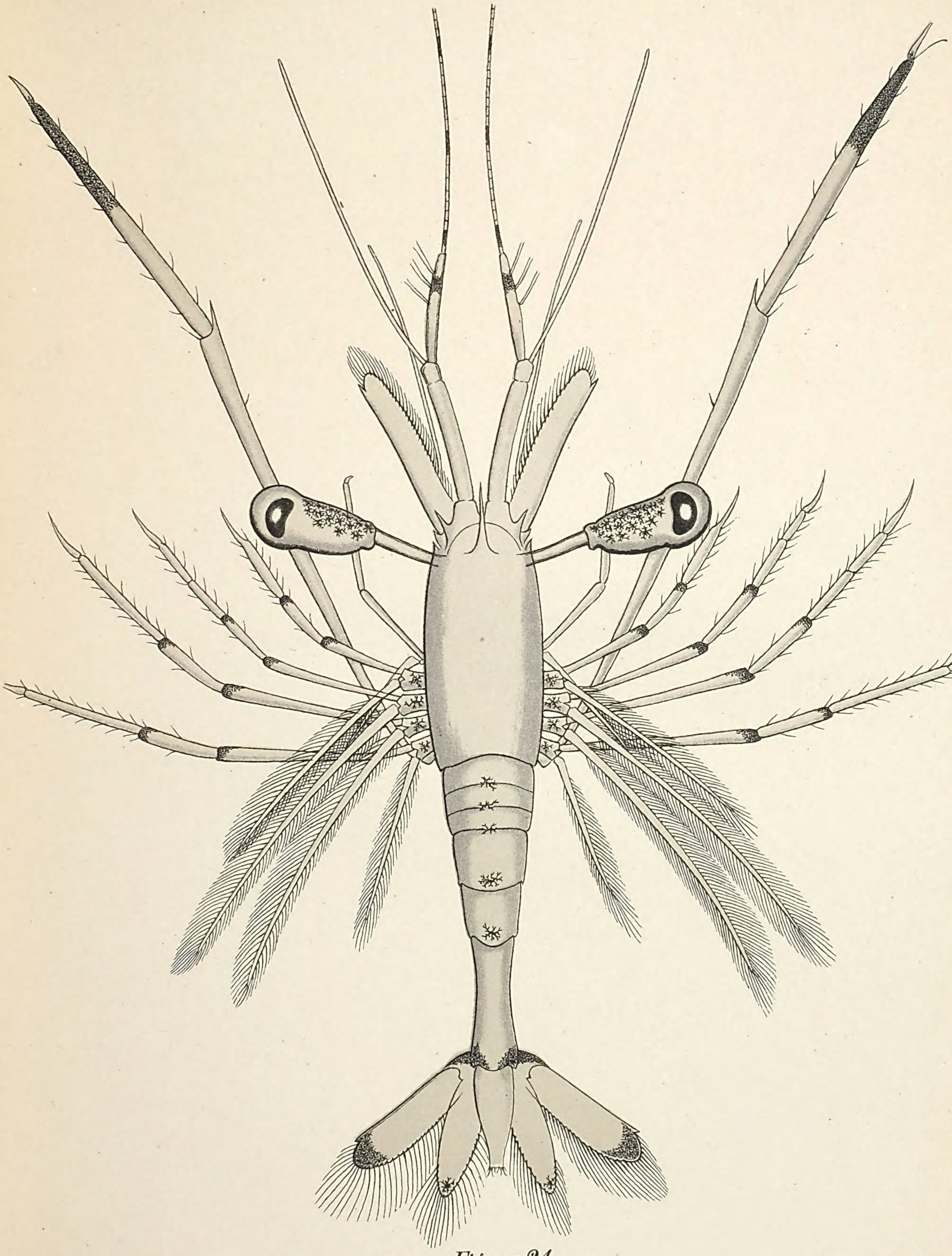


Figure 24.

W K. Brooks, del.

Sackett & Wilhelms Lithographing Co. New York.

STENOPUS

Plate XI.

Fig. 25. Embryo nearly ready to hatch, released from the egg membranes. ×70. Some food yolk is still unabsorbed; swimming hairs very rudimentary; compare Fig. 11.
Fig. 26. Right first antenna of older larva. ×70.
Fig. 27. Profile view of hinder end of abdomen of same larva. ×28.
Fig. 28. Second maxilla of same larva. ×276.
Fig. 29. Mandible of same larva. ×276.
Fig. 30. First maxilla of same larva. ×276.
Fig. 31. Portion of third maxilliped of same larva. ×70.
Fig. 32. Terminal segment of second pereiopod of same larva. ×70.
Fig. 33. First pereiopod of same larva. ×70.
Fig. 34. Portions of third, fourth, and rudimentary fifth pereiopods of same larva. ×70.

REFERENCE LETTERS.

A. I, first antenna.
A. II, second antenna.
Md., mandible.
Mxpd. I, III, first and third maxillipeds.
R., rostrum.
Th., *Th.* 1, first maxilliped.
Th. 3–*Th.* 5, third to fifth maxillipeds.
1, first maxilliped.

Fig.25.

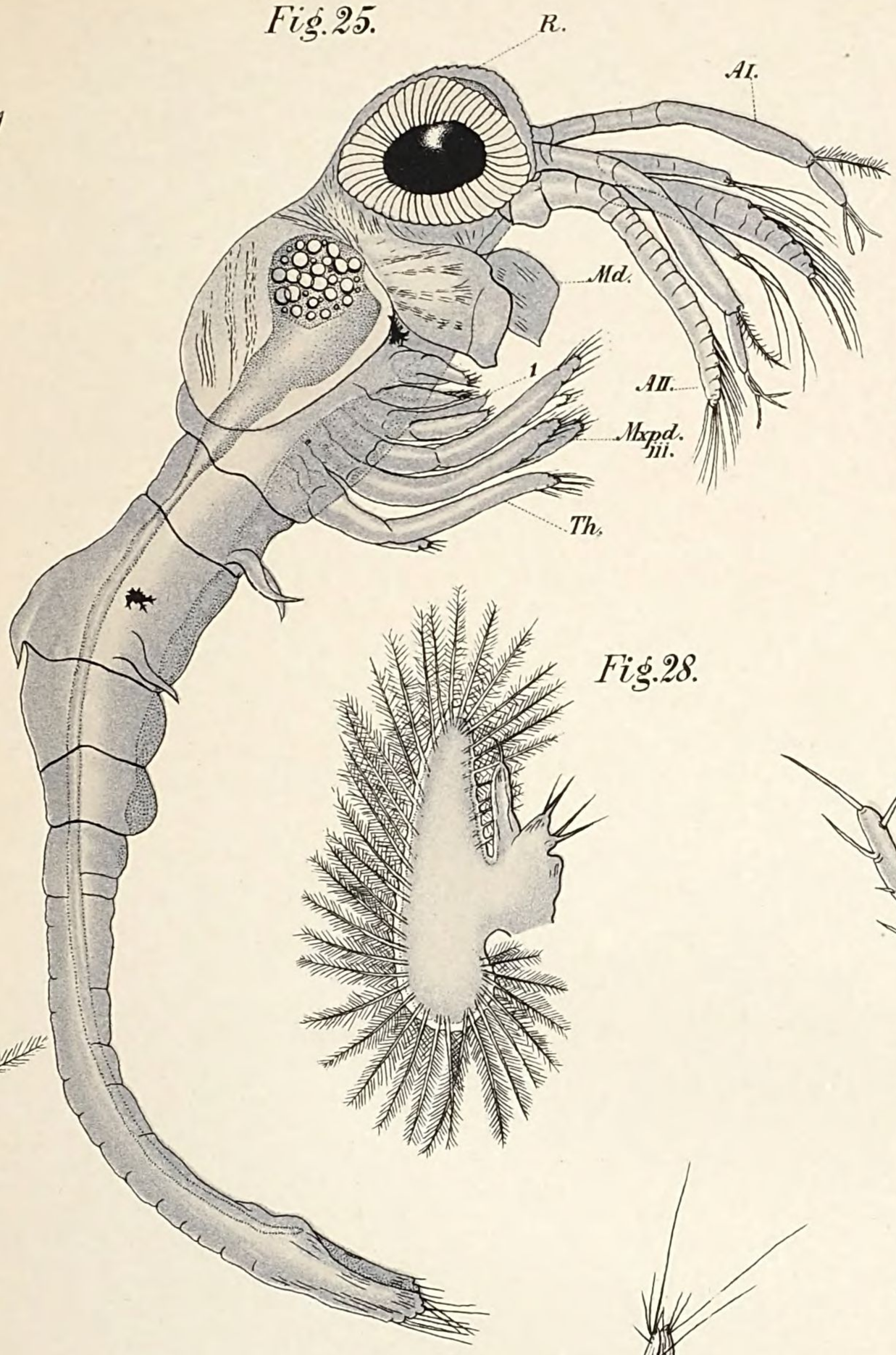


Fig.26.

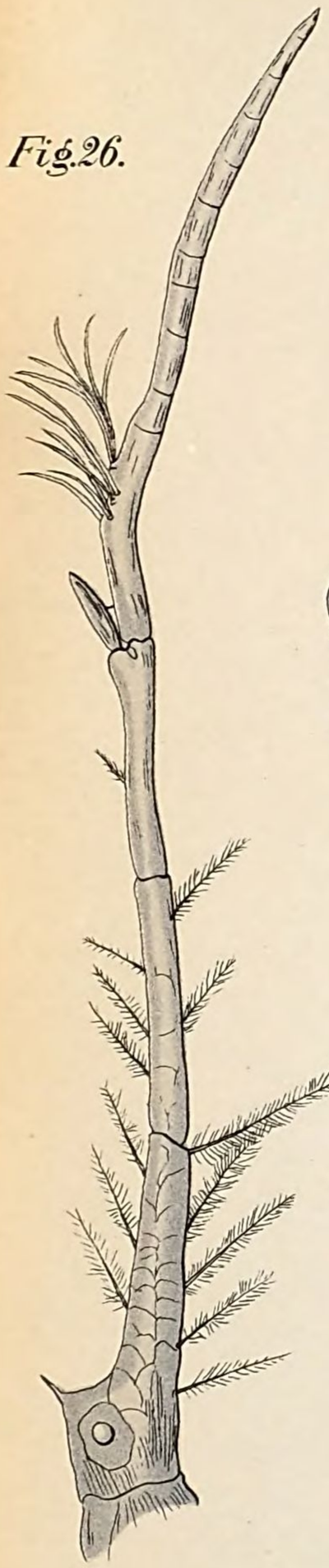


Fig.27.

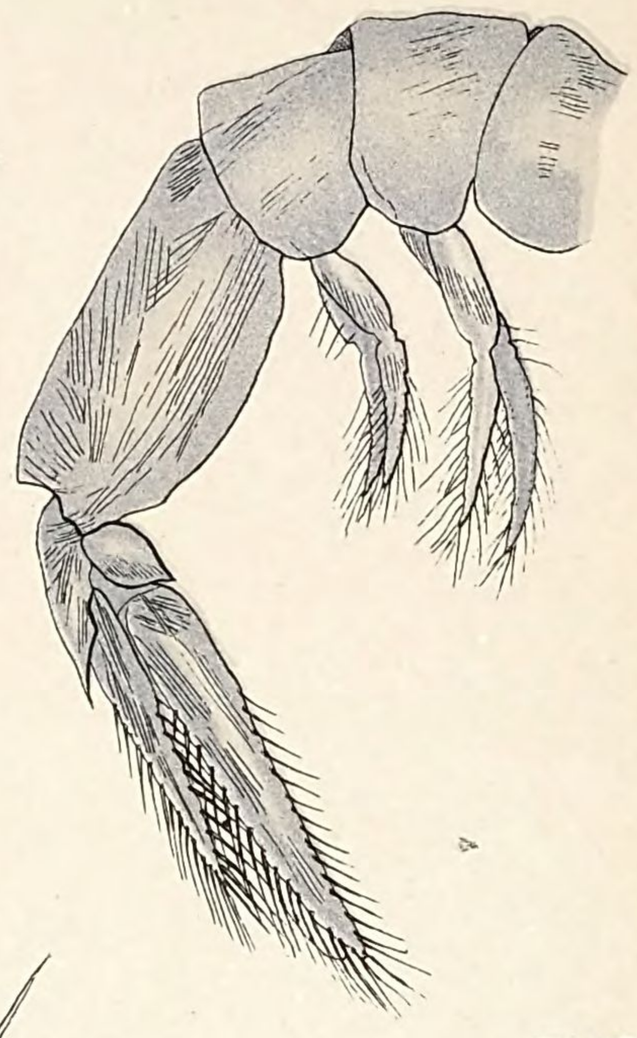


Fig.28.

Fig.29.

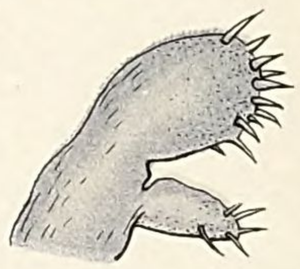


Fig.30.

Fig.31.



Fig.32.

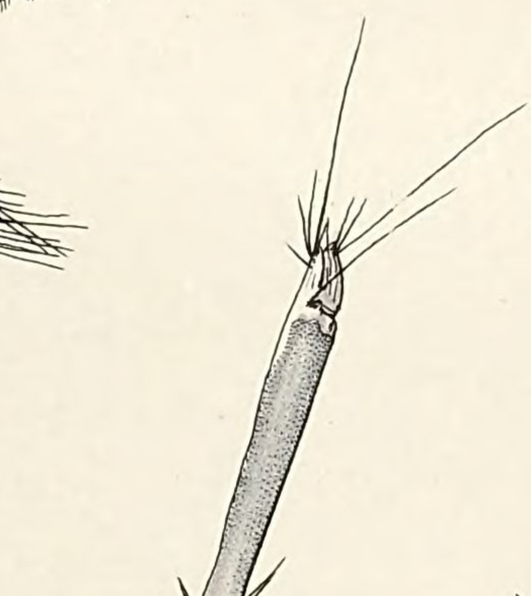


Fig.33.

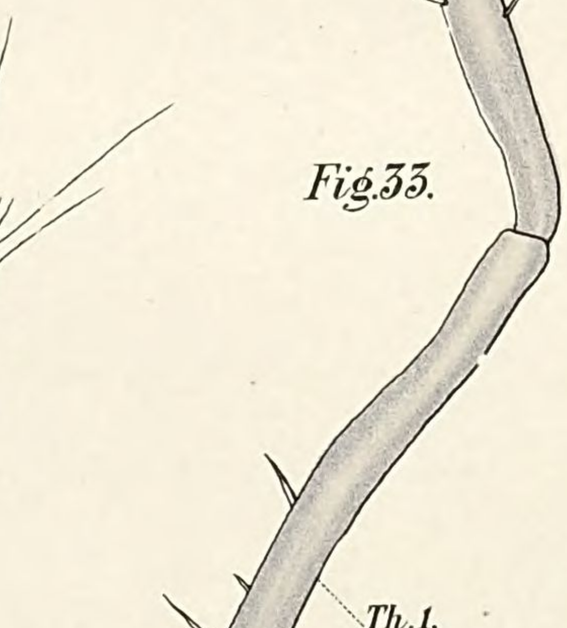
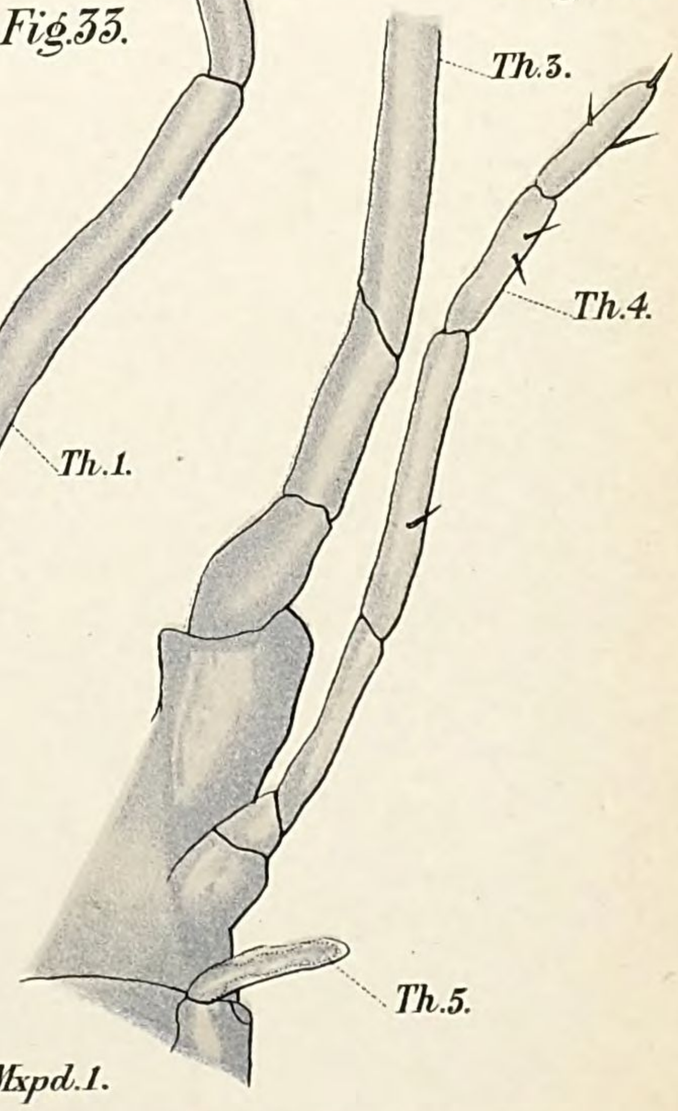


Fig.34.



F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

STENOPUS HISPIDUS.

Plate XII.

Fig. 35. Older larva, taken in the tow-net outside of Nassau Harbor May 7, 1887. L=9^{mm}. L. of eye-stalk=2^{mm}. L. between eyes=4.7^{mm}. ×15. The long flagella of the antennæ are conventionally represented to bring them into the plate. They trail above and behind the animal as it swims through the water.

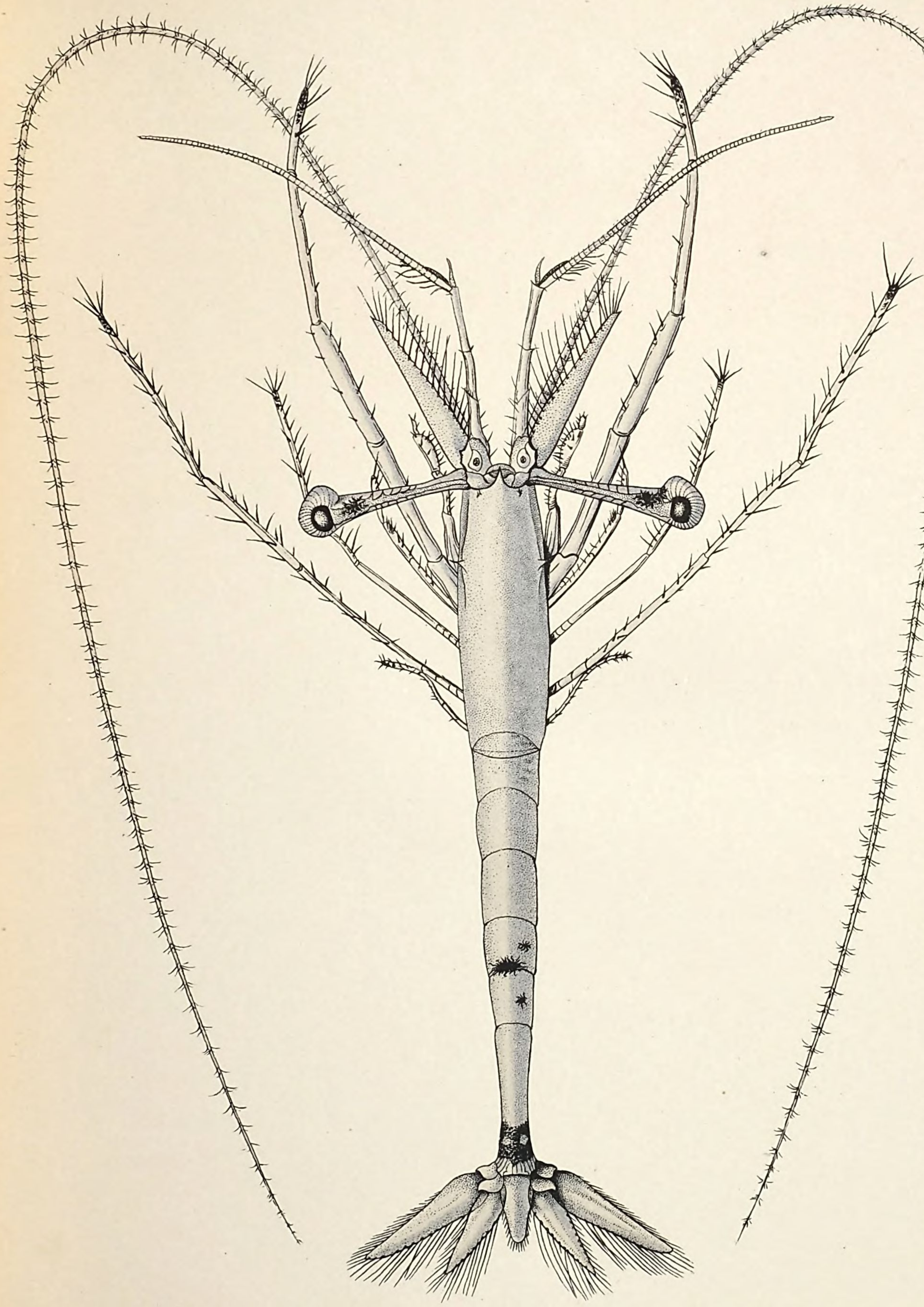


Figure 35.

F.H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

STENOPUS HISPIDUS.

Plate XIII.

Fig. 36. First maxilla, outer side. Adult male. ×15.
Fig. 37. Lateral view of carapace of adult male. ×5.
Fig. 38. Left mandible, outer side. Adult male. ×14.
Fig. 39. Stalk and portion of flagella of left first antenna, seen from above. Adult male. ×5.
Fig. 40. First right pleopod of male, outer side. ×14.
Fig. 41. Left second antenna with flagellum cut off near its base. Adult male. Seen from above. ×5.
Fig. 42. Second maxilla of adult male. ×14.
Fig. 43. Right first maxilliped from outer side. Adult male. ×14.
Fig. 44. Right second maxilliped, from outer side. Adult male. ×14.
Fig. 45. Right third maxilliped, from under side. Adult male. ×5.
Fig. 46. Right first pereiopod, under side. Adult male. ×5.
Fig. 47. Right fifth pereiopod, under side. Adult male. ×5.

Fig.36.

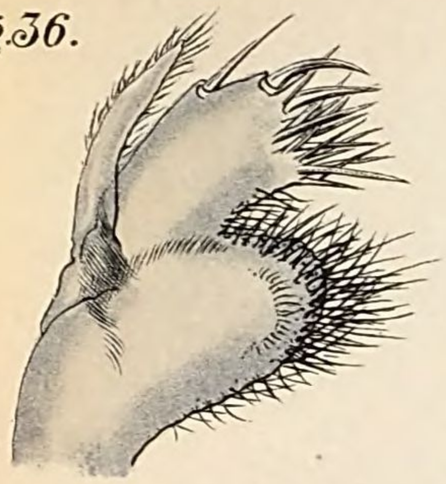


Fig.37.

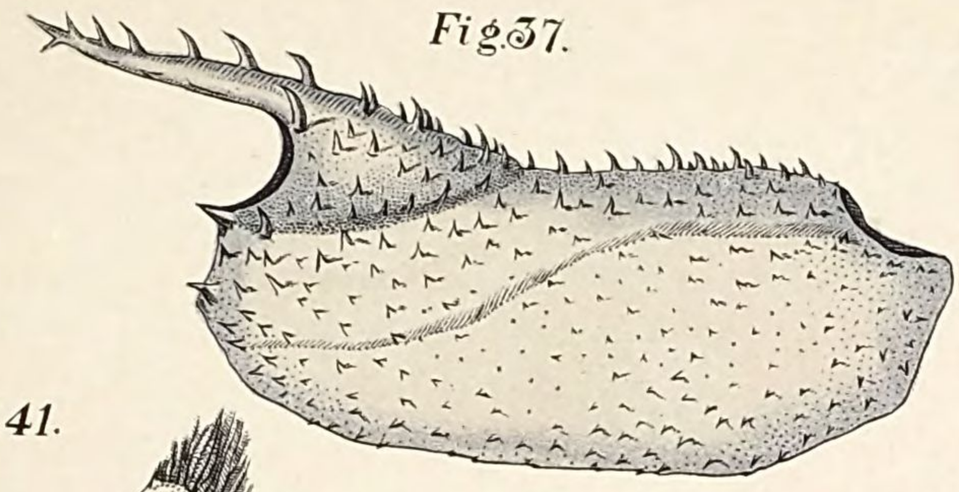


Fig.38.

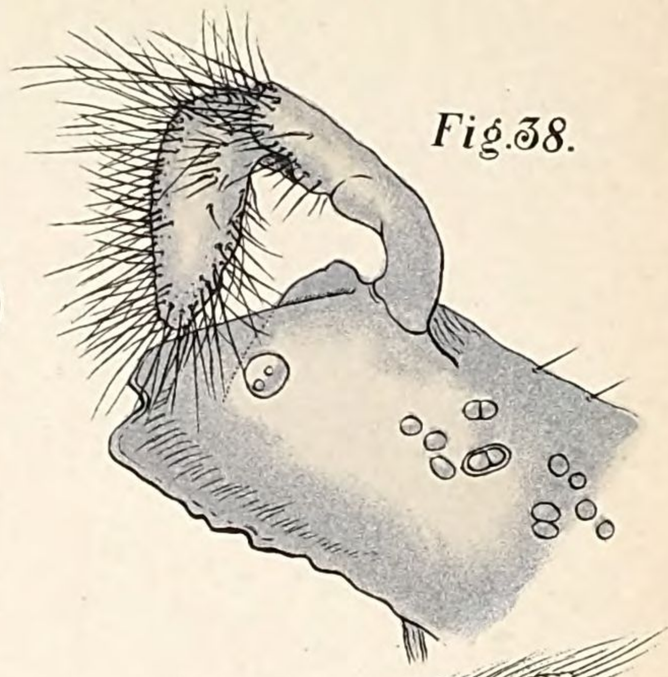


Fig.39.



Fig.41.



Fig.42.

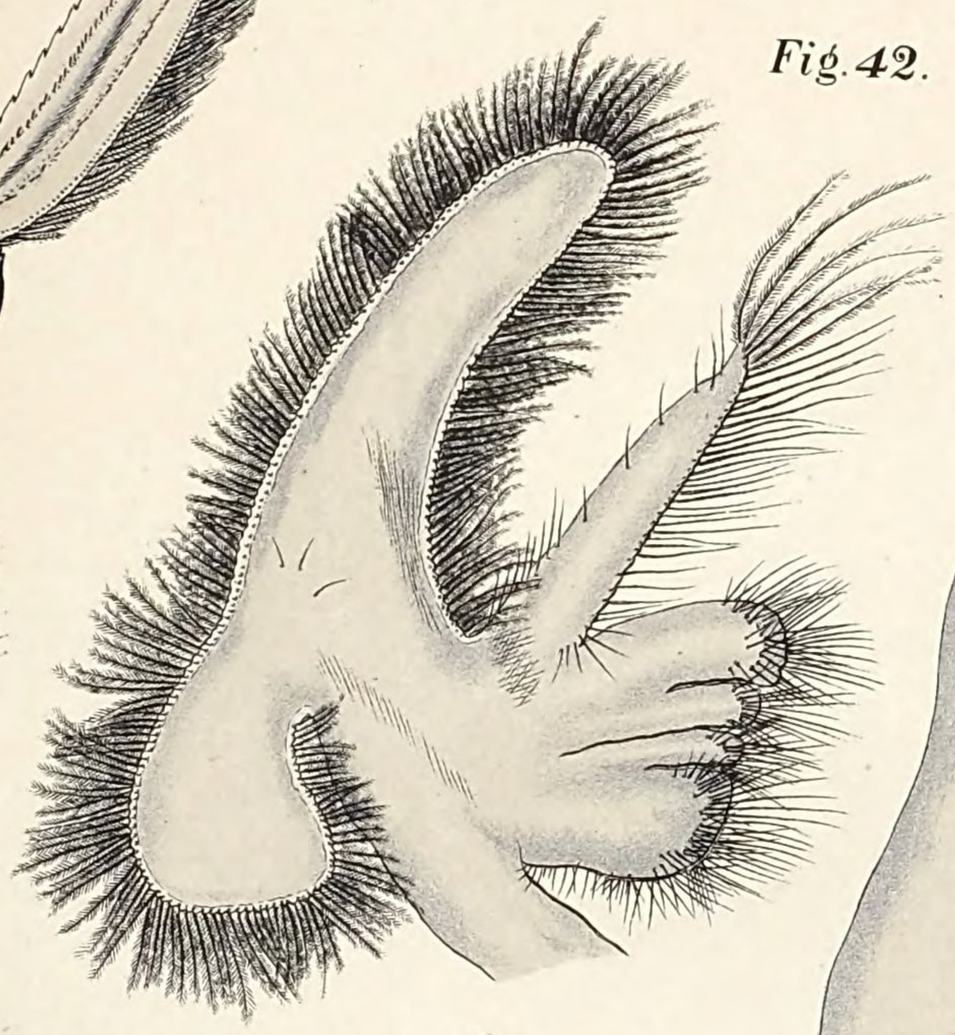


Fig.43.

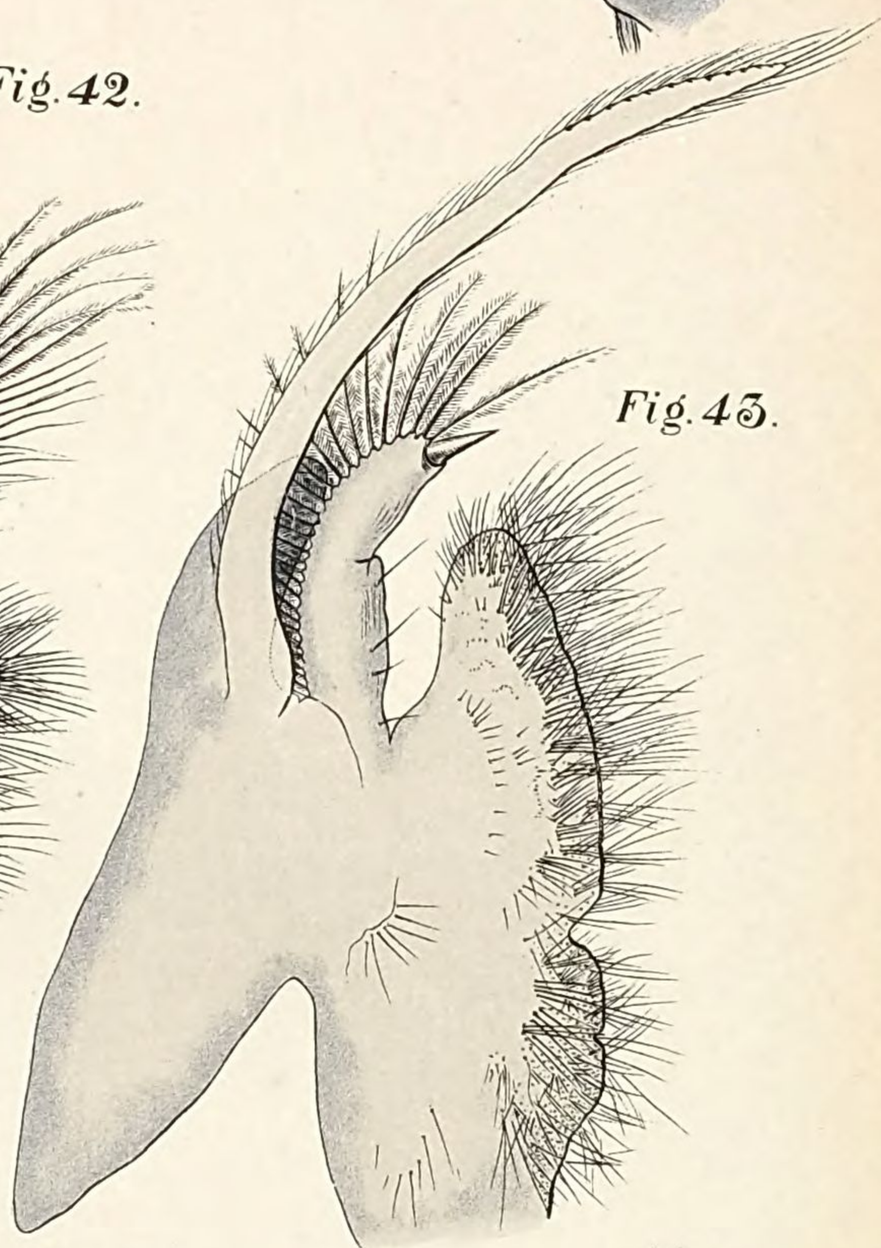


Fig.40.

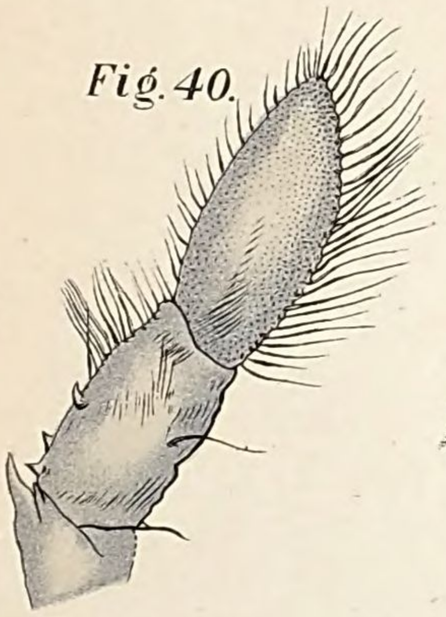


Fig.44.

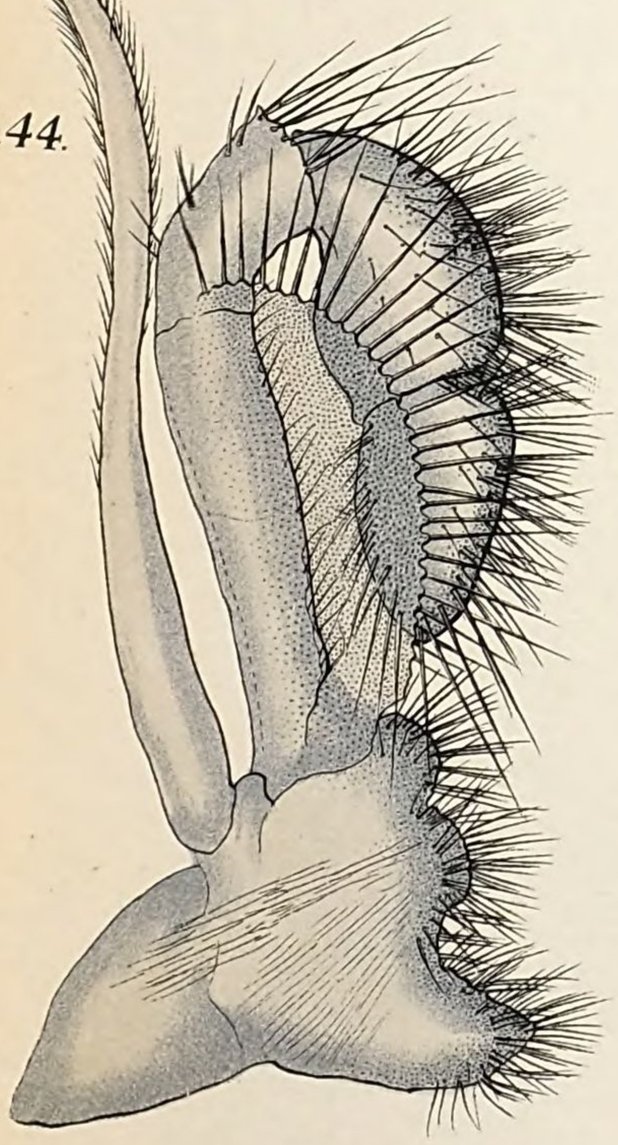


Fig.45.

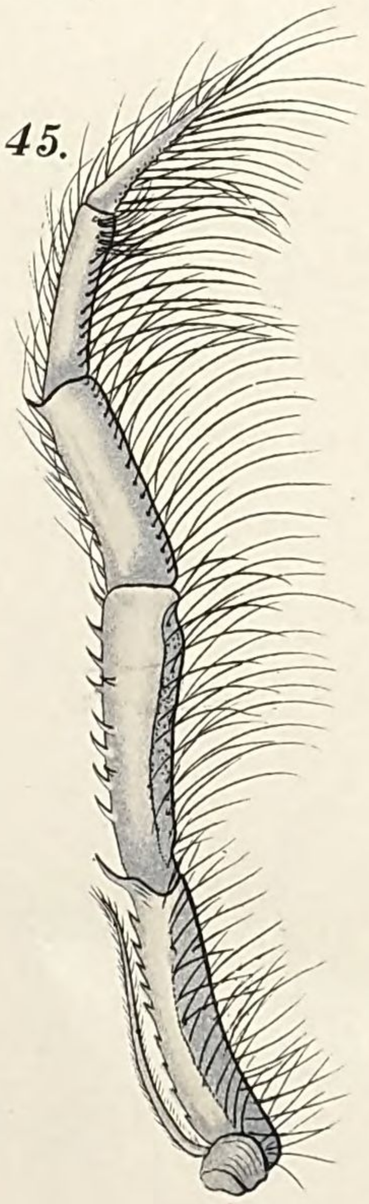


Fig.46.

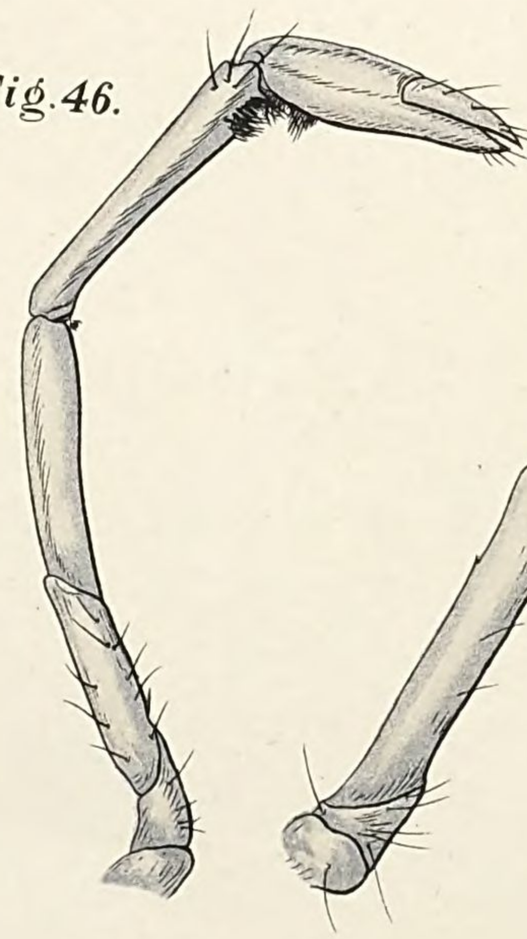
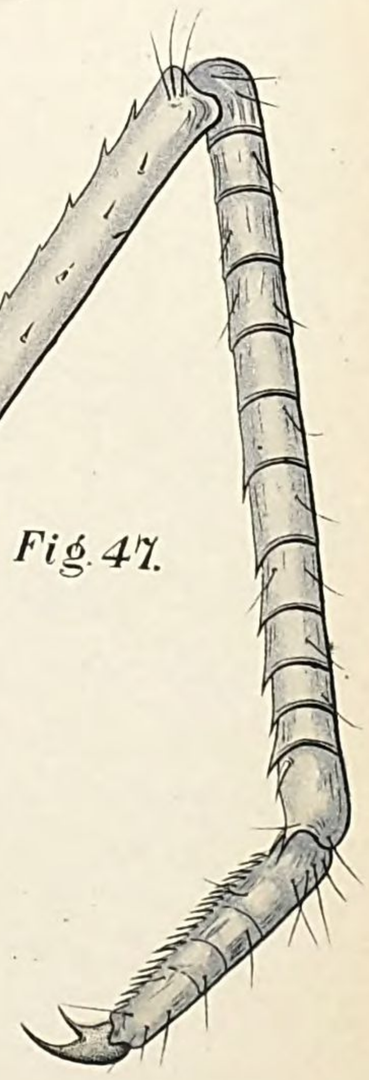


Fig.47.



F.H.Herrick, del.

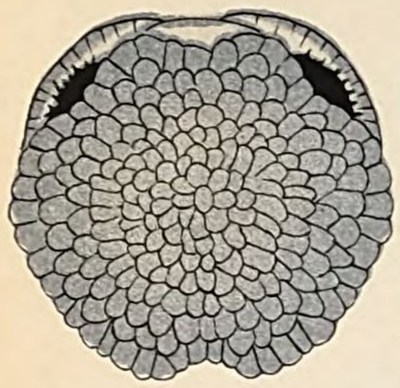
Sackett & Wilhelms Lithographing Co. New York

STENOPUS HISPIDUS.

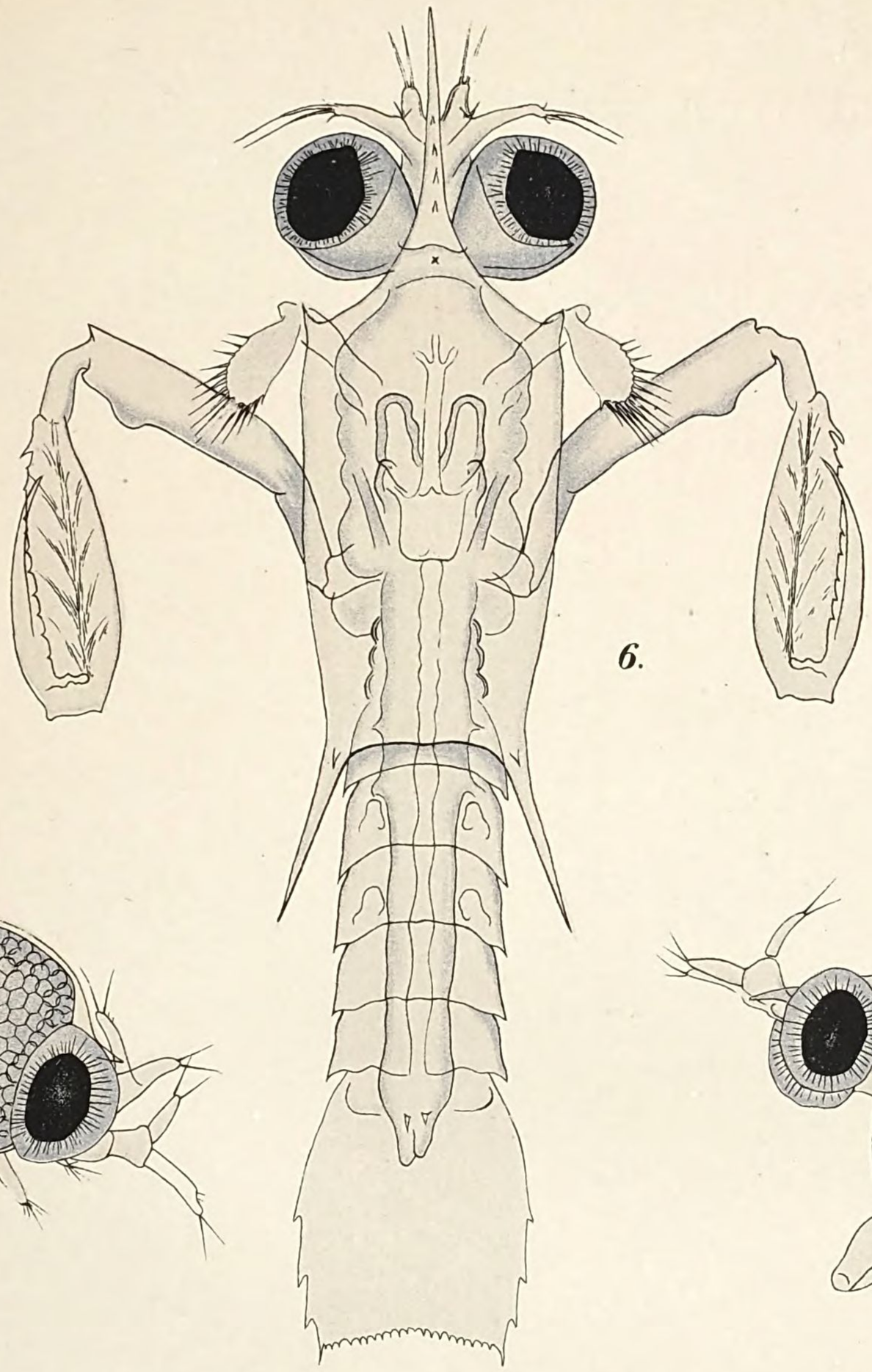
PLATE XIV.

Metamorphosis of Gonodactylus chiragra, drawn from life by W. K. Brooks.

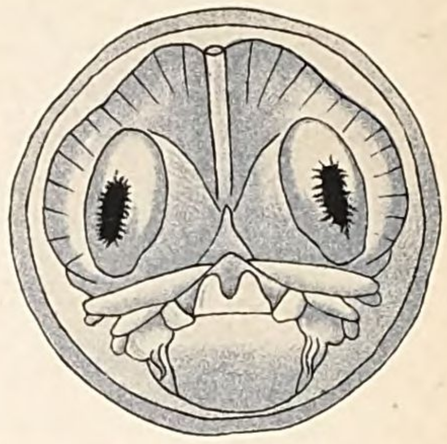
FIG. 1. Dorsal view of egg just before hatching.
FIG. 2. Front view of the same egg.
FIG. 3. Side view of the larva immediately after hatching.
FIG. 4. Side view of the same larva after the first molt.
FIG. 5. Side view of the same larva after the second molt.
FIG. 6. Dorsal view of the larva at the beginning of its pelagic life.



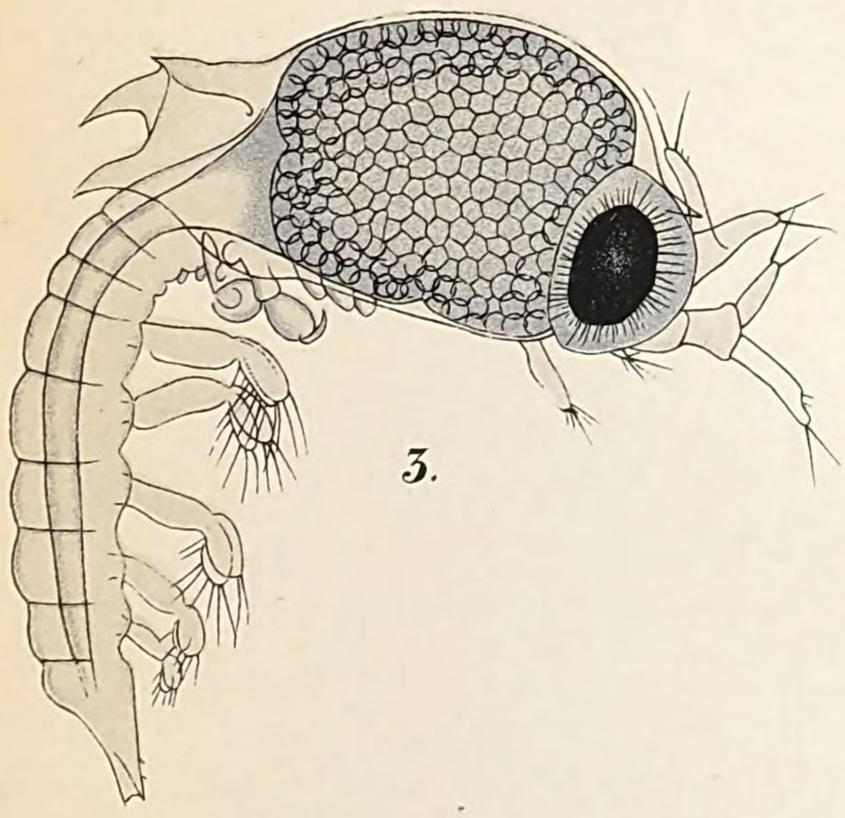
1.



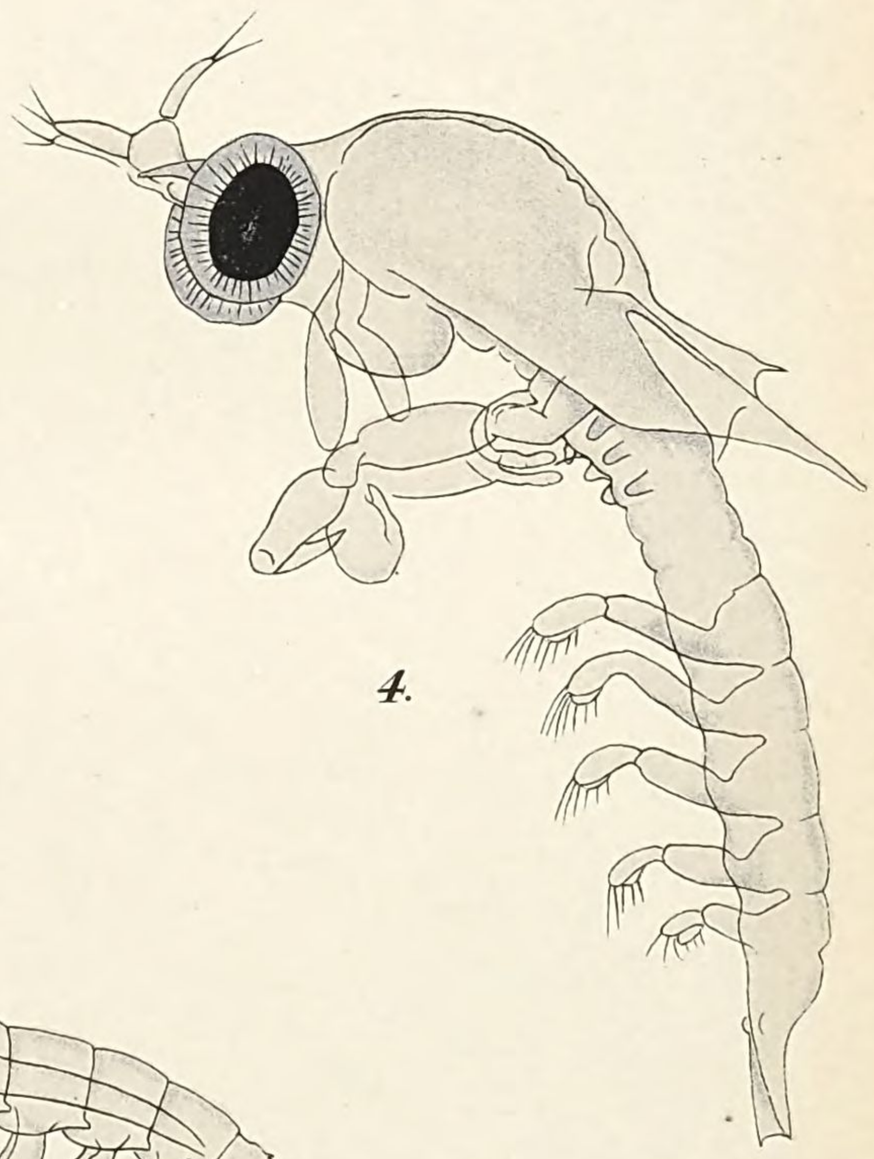
6.



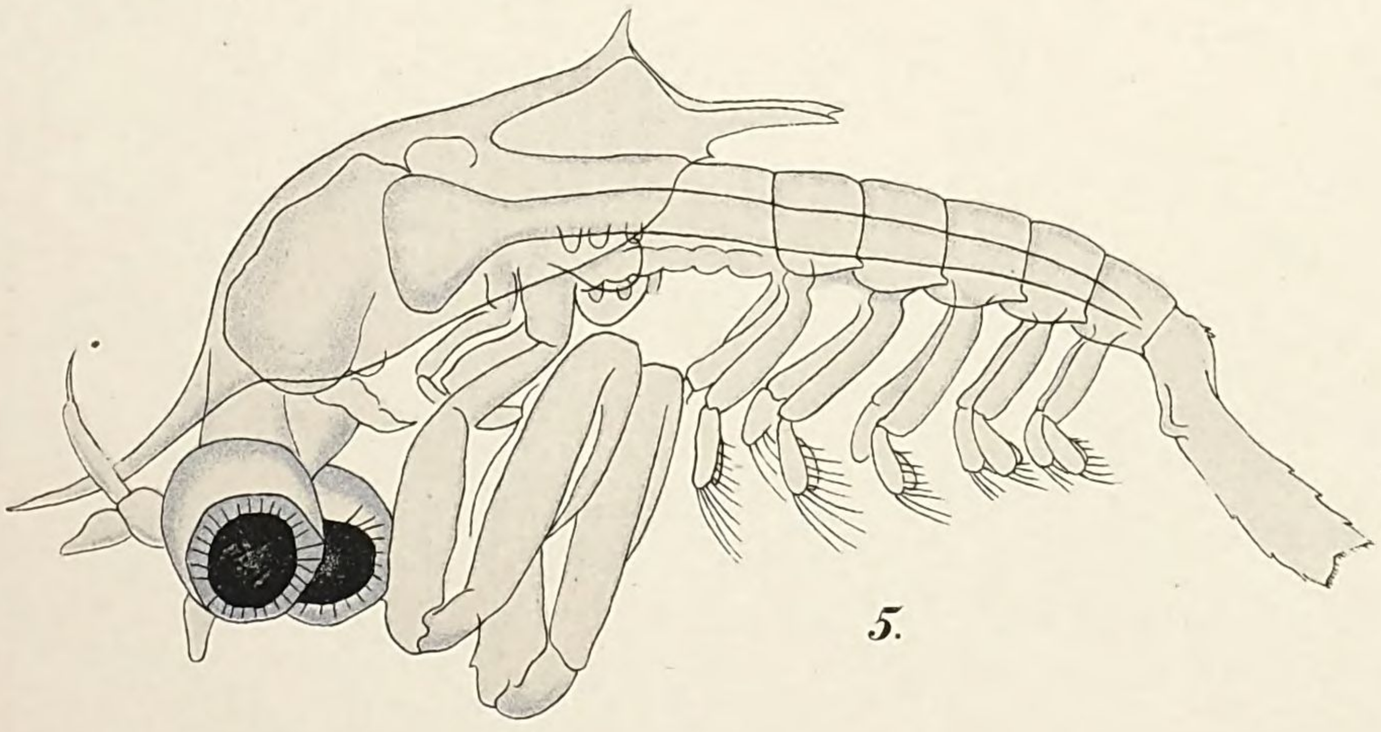
2.



3.



4.



5.

W. K. Brooks, del.

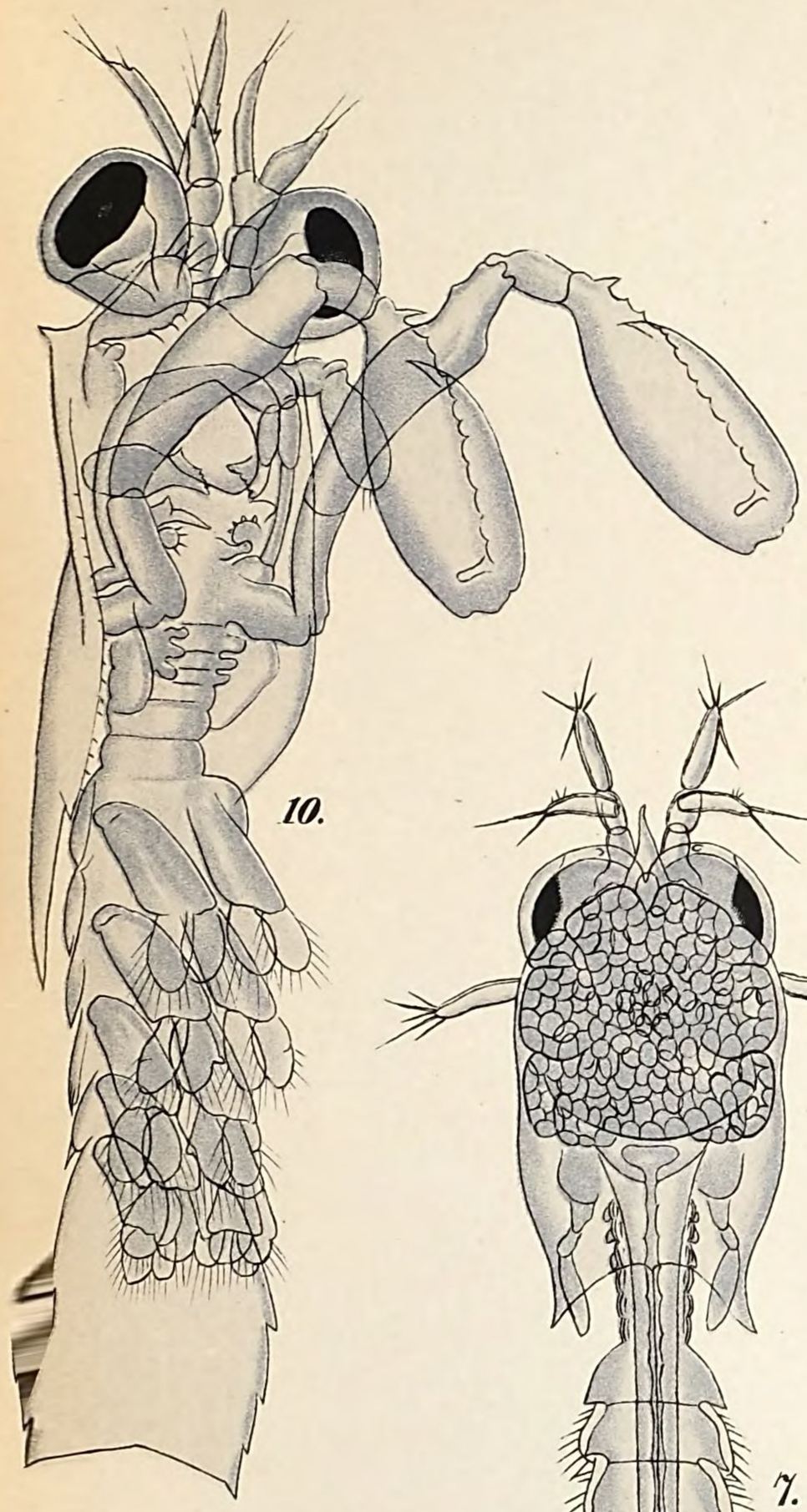
Sackett & Wilhelms Lithographing Co. New York.

GONODACTYLUS CHIRAGRA.

Plate XV.

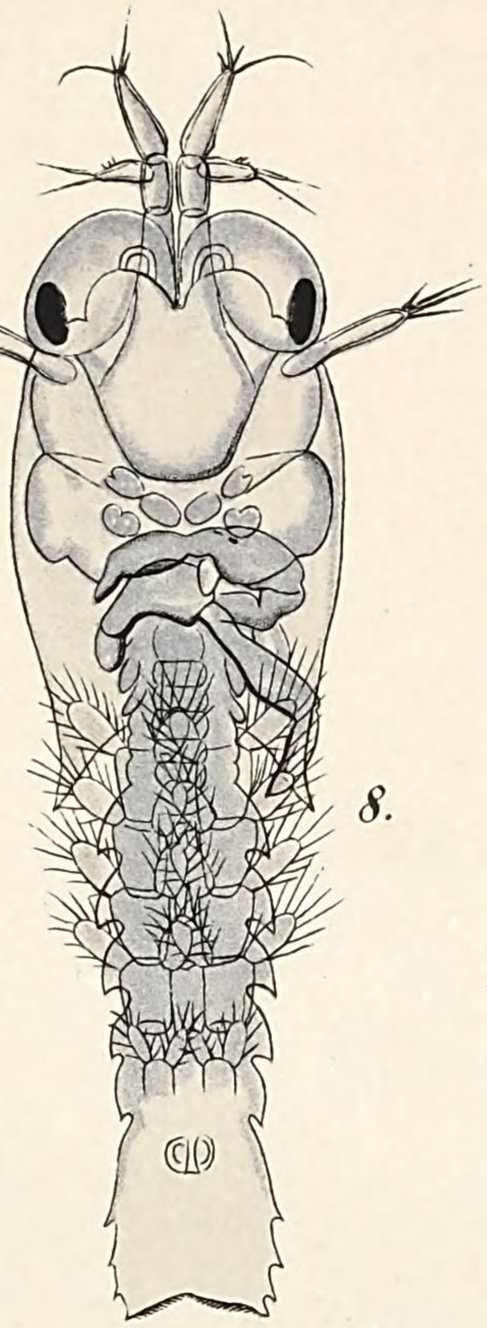
Metamorphosis of Gonodactylus chiragra, drawn from life by W. K. Brooks.

Fig. 7. Dorsal view of the larva shown in Pl. xiv, Fig. 3.
Fig. 8. Ventral view of the same larva.
Fig. 9. Dorsal view of the larva shown in Pl. xiv, Fig. 4.
Fig. 10. Ventral view of the larva shown in Pl. xiv, Fig. 5.
Fig. 11. An older larva in dorsal view.
Fig. 12. Same in ventral view.
Fig. 13. Raptorial claw of a still older larva.

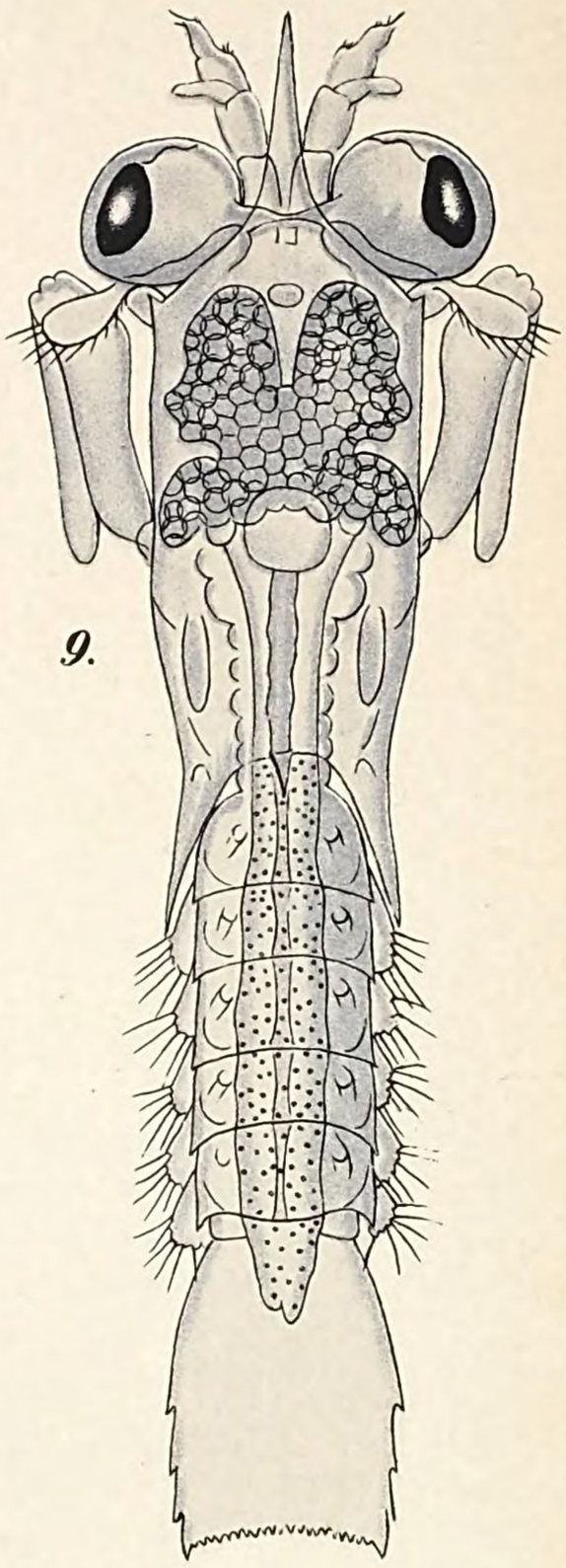


10.

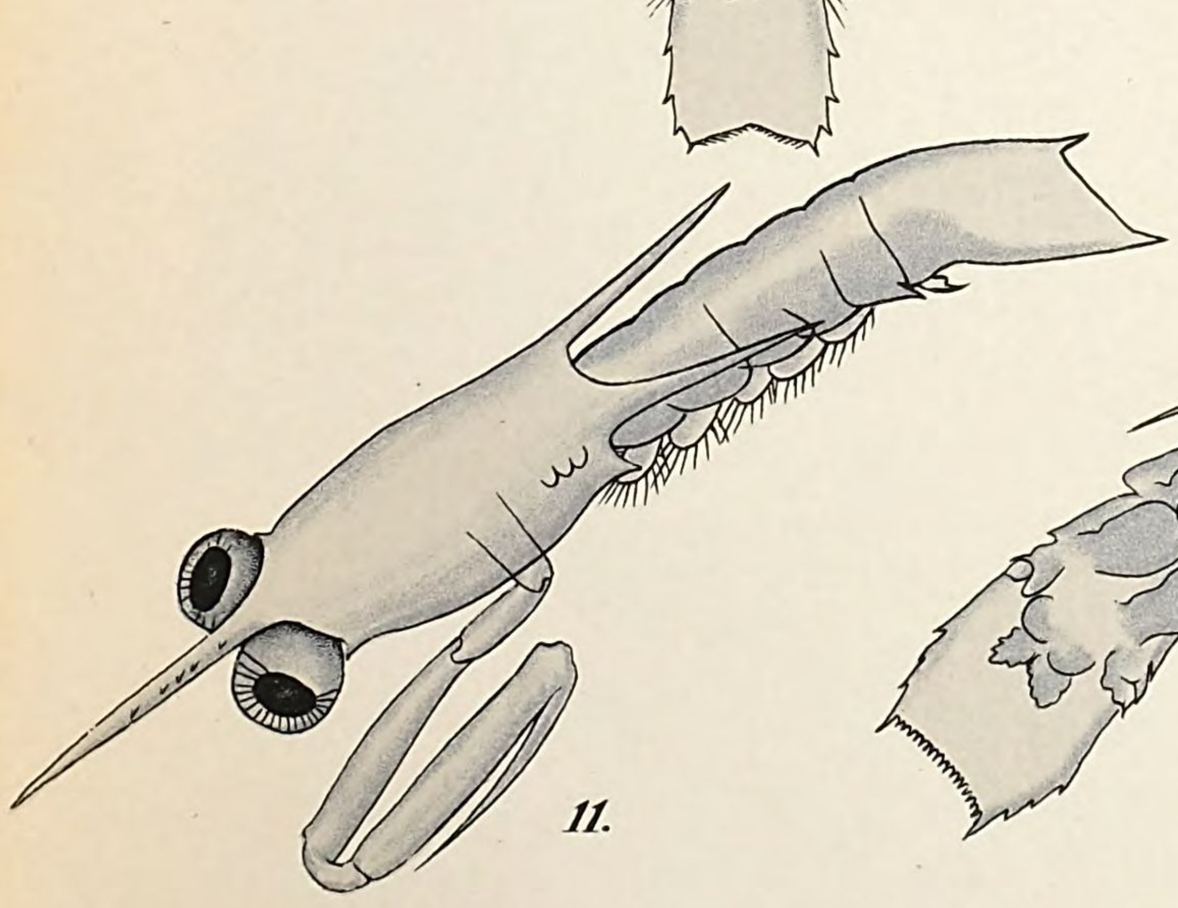
7.



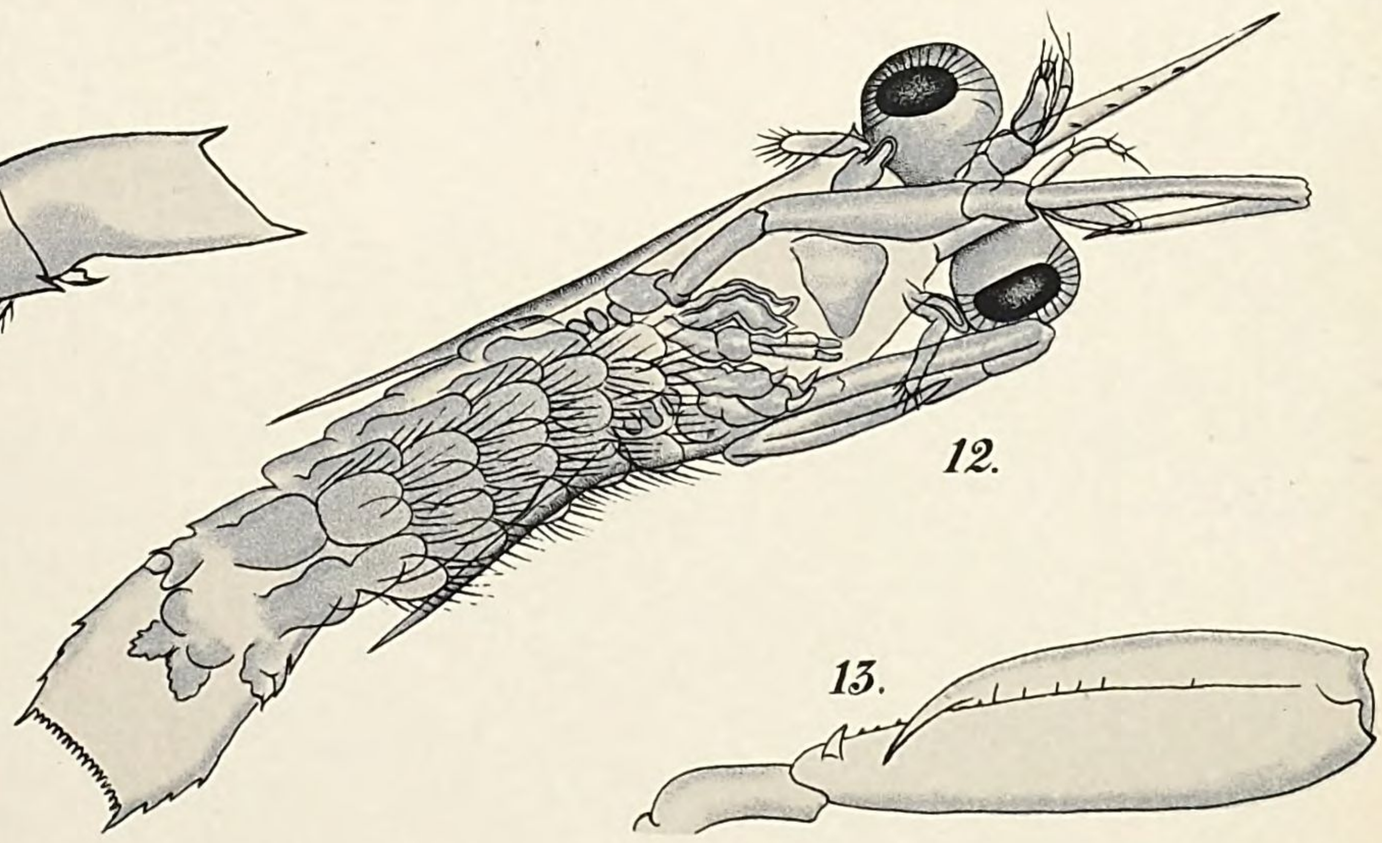
8.



9.



11.



12.

13.

W.K. Brooks, del.

Sackett & Wilhelms Lithographing Co. New York

GONODACTYLUS CHIRAGRA.

Plate XVI.

Metamorphosis of Alpheus, drawn by W. K. Brooks and F. H. Herrick.

Fig. 1. Third larval stage of *Alpheus minor* from below, drawn by W. K. Brooks.

Fig. 2. Second larval stage of *Alpheus minor*, about one-tenth of an inch long, drawn from below by W. K. Brooks.

Fig. 3. Telson of the Nassau form of *Alpheus heterochelis* during the second larval stage, drawn at 10 a. m., April 17, 1887, by F. H. Herrick.

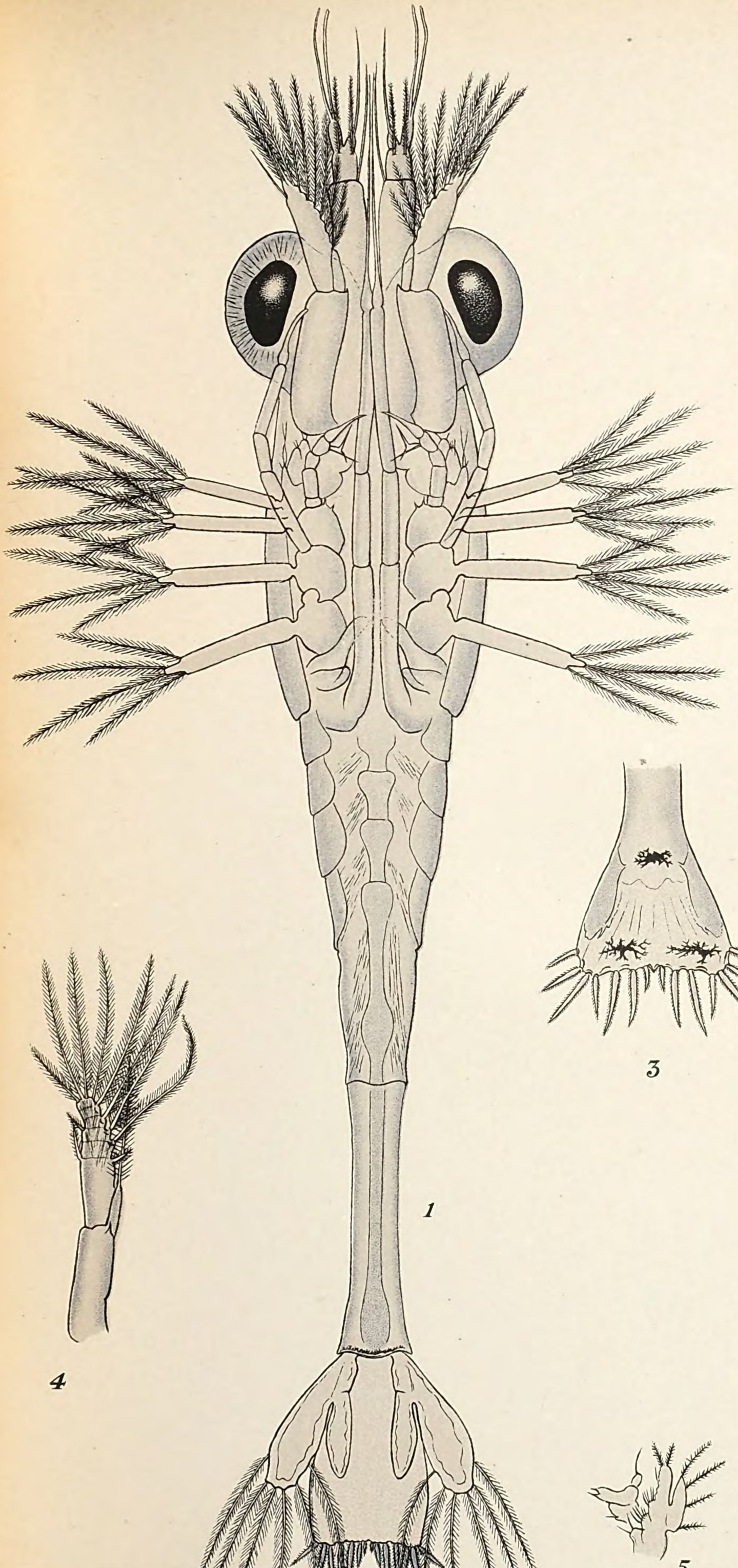
Fig. 4. Second antenna of *Alpheus minor* during the first larval stage, from the inside drawn by W. K. Brooks, May 13, 1881, D. 2. (Zeiss lenses.)

Fig. 5. First and second maxillæ of the Nassau form of *Alpheus heterochelis* during the fourth larval stage, drawn by W. K. Brooks from a sketch by F. H. Herrick. The larva at this stage is shown in Pl. xii, Fig. 3.

Fig. 6. First maxilla of *Alpheus minor* during the first larval stage, drawn at Beaufort, June 2, 1881, by W. K. Brooks, D. 2.

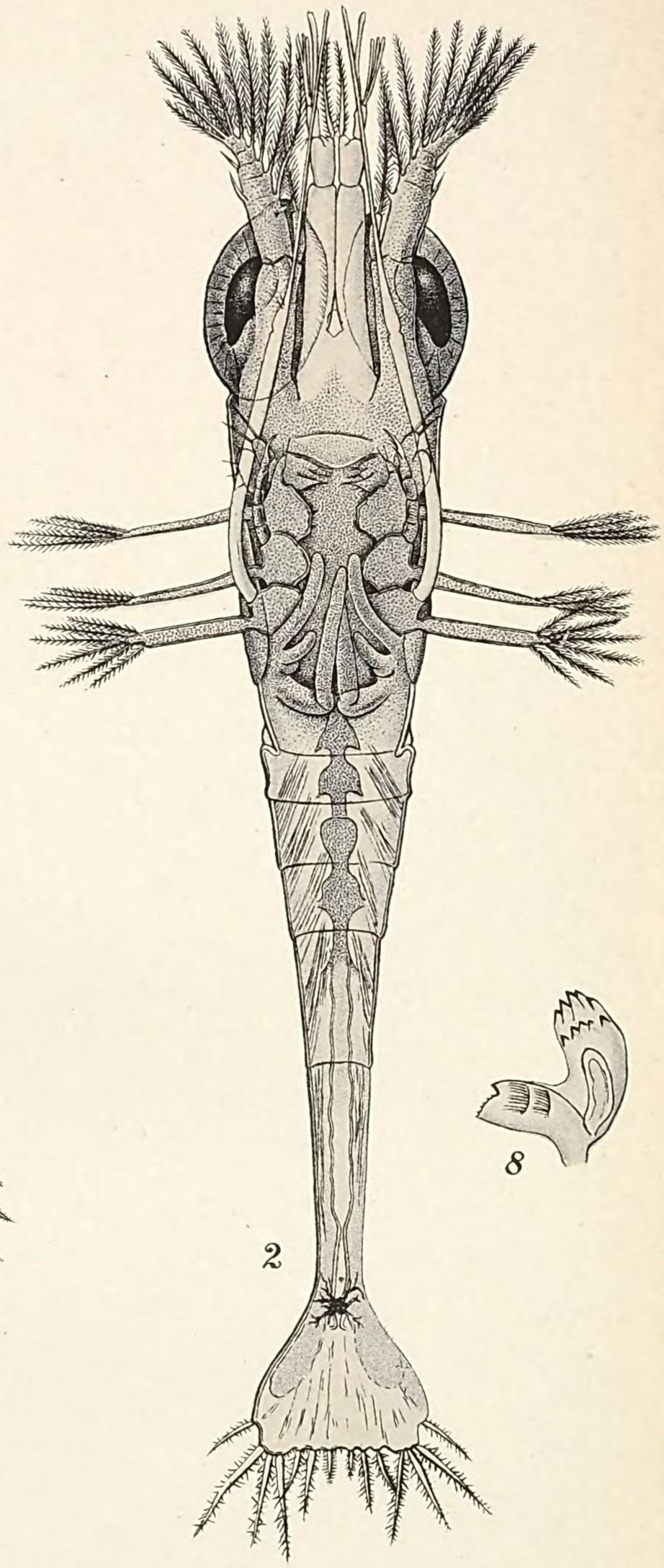
Fig. 7. Second maxilla of the same larva.

Fig. 8. Mandible of the same larva.



1

3



2

8

4

5

6

7

Brooks, & Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

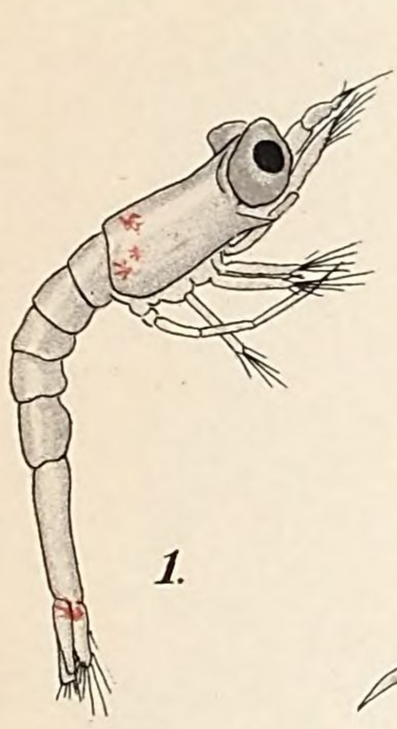
PLATE XVII.

Metamorphosis of Alpheus, drawn from nature by W. K. Brooks.

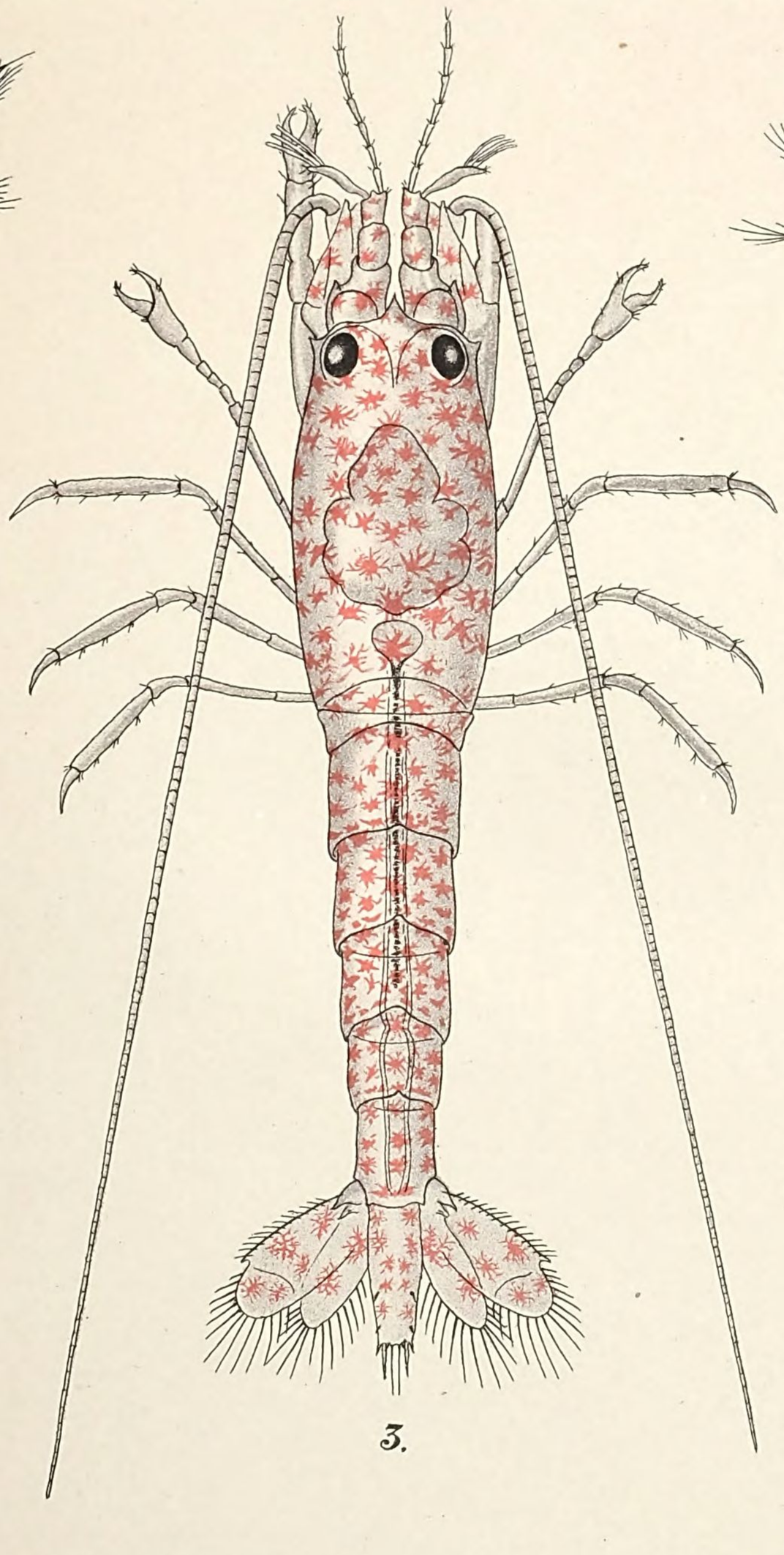
FIG. 1. Side view of *Alpheus minor* after the second molt and in the third larval stage. Zeiss A. 2. This larva was about ninety-five one-thousandths of an inch long from the tip of the rostrum to the tip of the telson.

FIG. 2. Dorsal view of *Alpheus minor* after the first molt and in the second larval stage. This specimen was hatched at 9 p. m., May 30, 1881, and the drawing was made at 9 a. m. on May 31. The specimen was eight one-hundredths of an inch long.

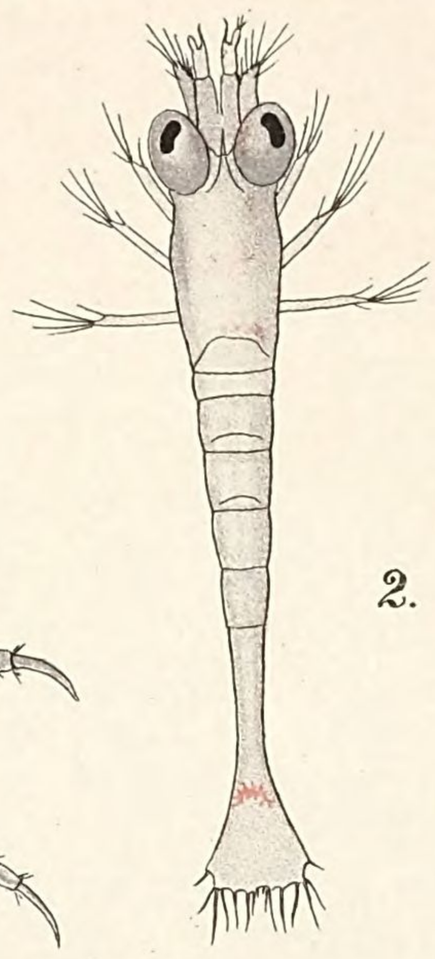
FIG. 3. Dorsal view of a young specimen of *Alpheus heterochelis* from Beaufort. The specimen was one-fifth of an inch long. It was reared from the egg in an aquarium in the laboratory, and it was fifteen days old when the drawing was made. It is a little older than those which are shown in Pl. xx, Figs. 2 and 3.



1.



3.



2.

W. K. Brooks, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

PLATE XVIII.

Metamorphosis of Alpheus, drawn by W. K. Brooks from sketches by F. H. Herrick.

FIG. 1. Side view of first or second larval stage of *Alpheus heterochelis* from Nassau, drawn on the night of April 15, 1887. Zeiss A. camera.

FIG. 2. Ventral view of the third larval stage of *Alpheus heterochelis* from Nassau, drawn April 18, 1887.

FIG. 3. Ventral view of fourth larval stage of *Alpheus heterochelis* from Nassau, drawn April 21, 1887.

FIG. 4. First maxilliped of the first larval stage of *Alpheus minor*.

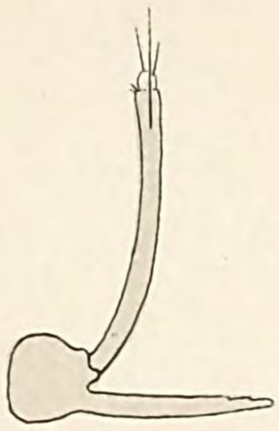


Fig. 4.

Fig. 1.

Fig. 2.

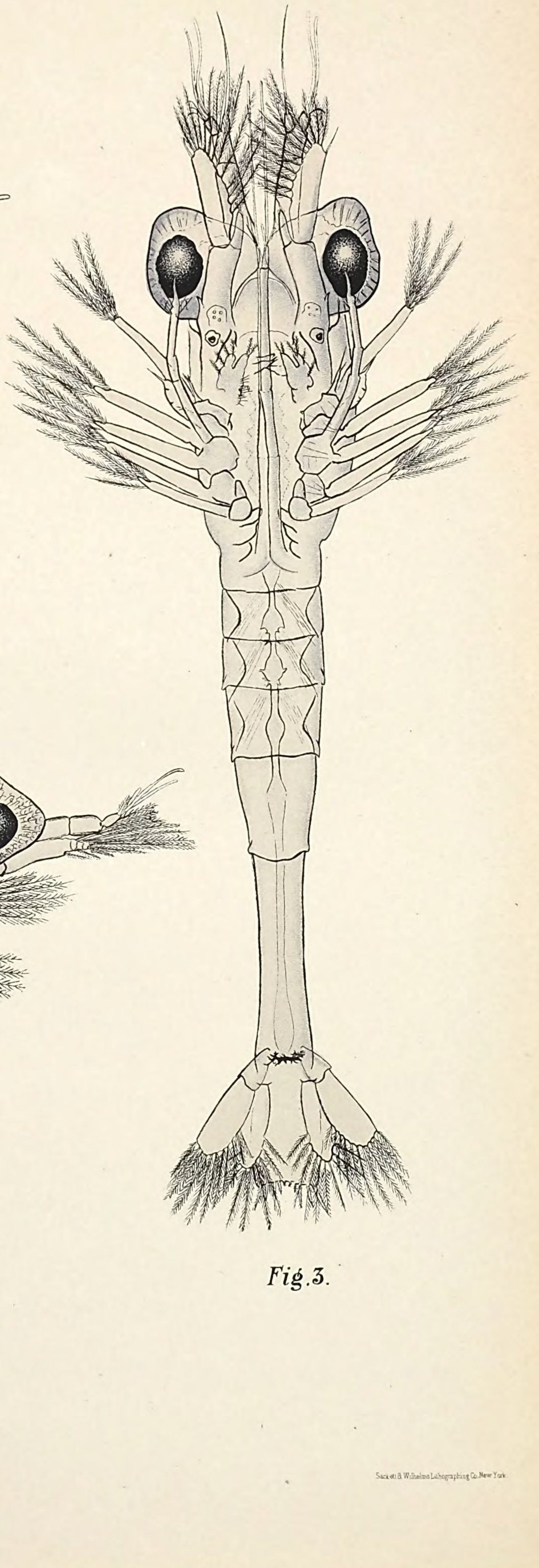


Fig. 3.

Brooks, & Herrick, del.

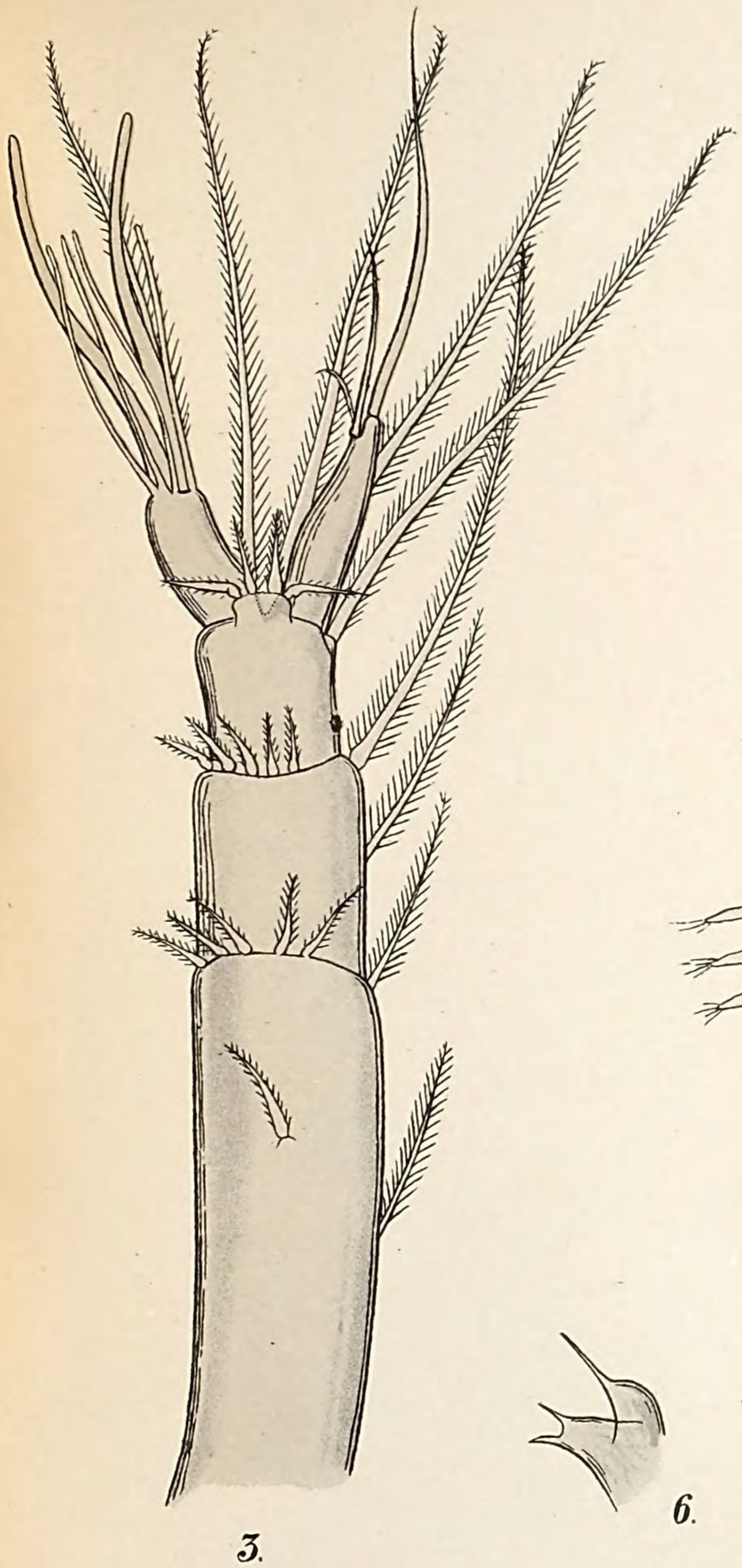
Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

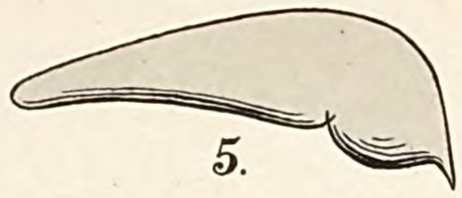
Plate XIX.

Metamorphosis of Alpheus heterochelis at Beaufort, North Carolina, drawn from nature by W. K. Brooks.

Fig. 1. Ventral view of the larva immediately after hatching.
Fig. 2. Side view of the same larva.
Fig. 3. Dorsal view of the antennule of the same larva.
Fig. 4. Ventral view of the antenna of the same larva.
Fig. 5. Mandible of the same larva.
Fig. 6. First maxilla of the same larva.
Fig. 7. Second maxilla of the same larva.

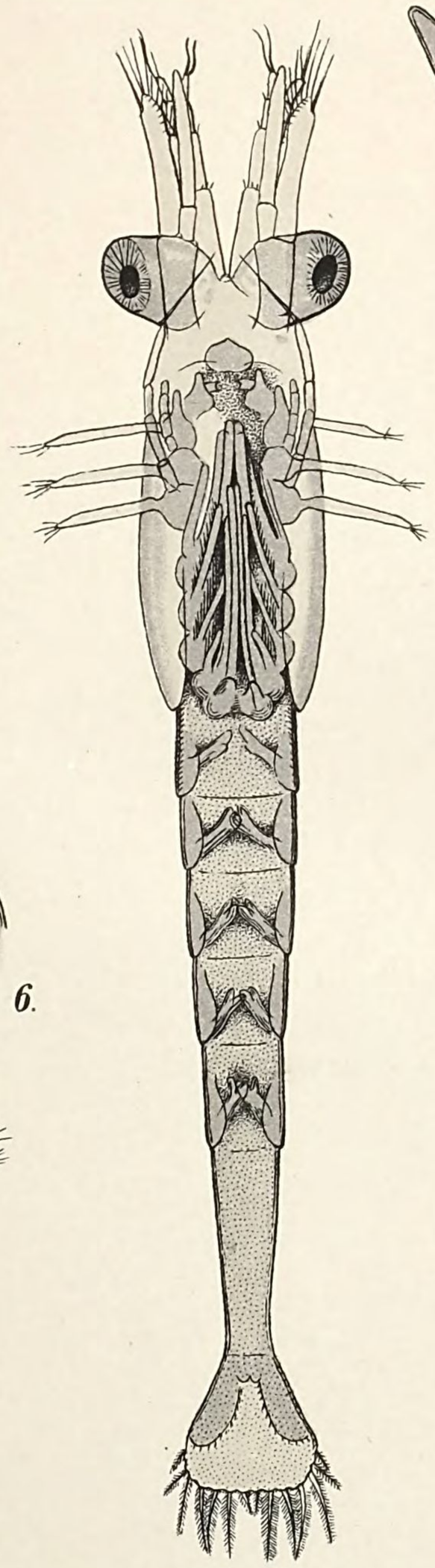


3.

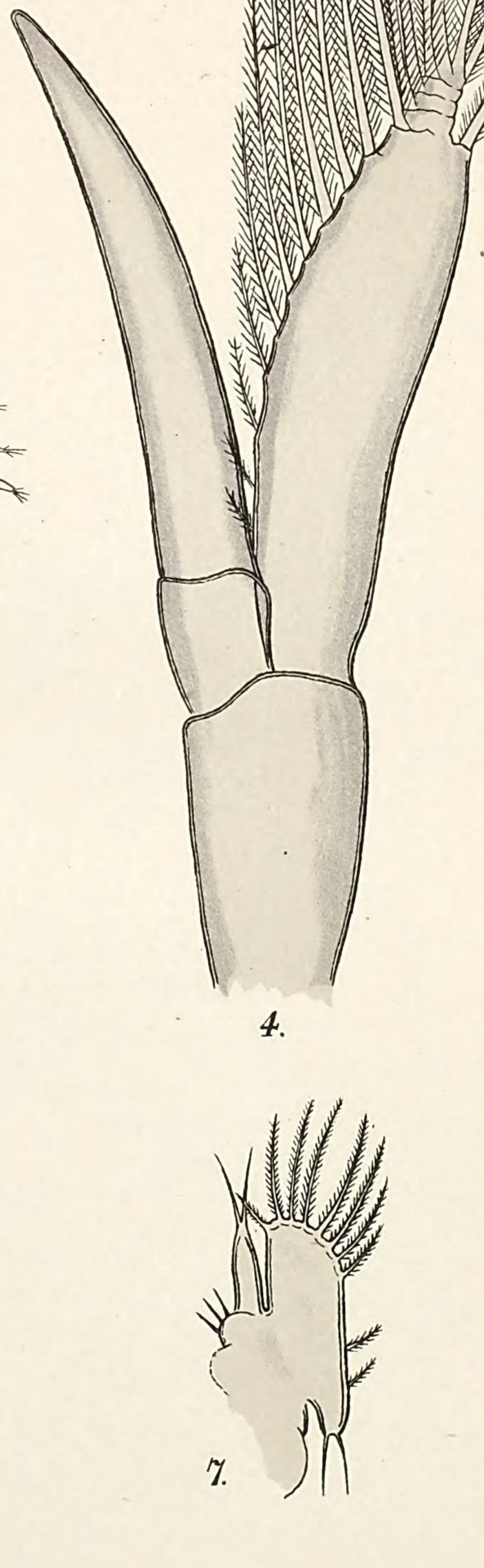


5.

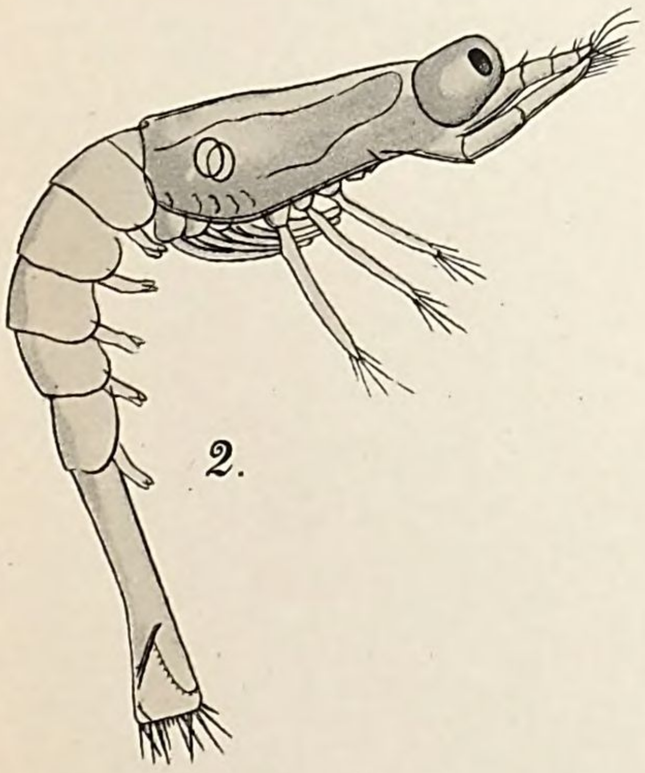
6.



1.



4.



2.

7.

W. K. Brooks, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

PLATE XX.

Metamorphosis of Alpheus heterochelis from Beaufort, North Carolina, drawn from nature by W. K. Brooks.

FIG. 1. Embryo just before hatching.

FIG. 2. View of a larva which was captured in the tow net at Old Topsail Inlet, North Carolina, June 25, 1883. It is about eighteen one-hundredths of an inch long, and is a little younger than the one shown in Pl. XVII, Fig. 3, and a little older than that shown in Fig. 3 of this plate.

FIG. 3. Ventral view of a larva little younger than Fig. 2.

FIG. 4. Telson and swimming appendages of the larva shown in Fig. 3.

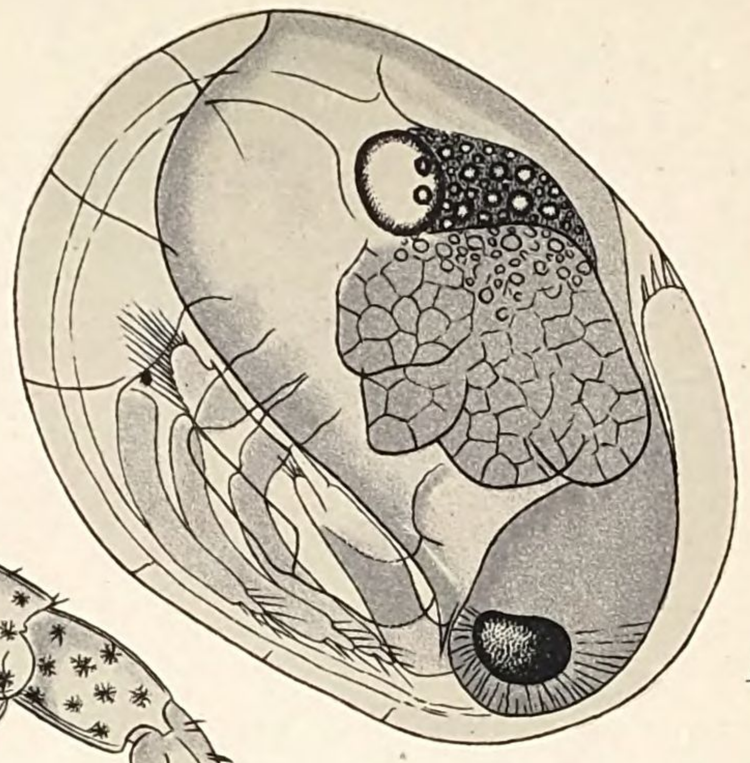
FIG. 5 First maxilla of the same larva.

FIG. 6. Second maxilla of the same larva.

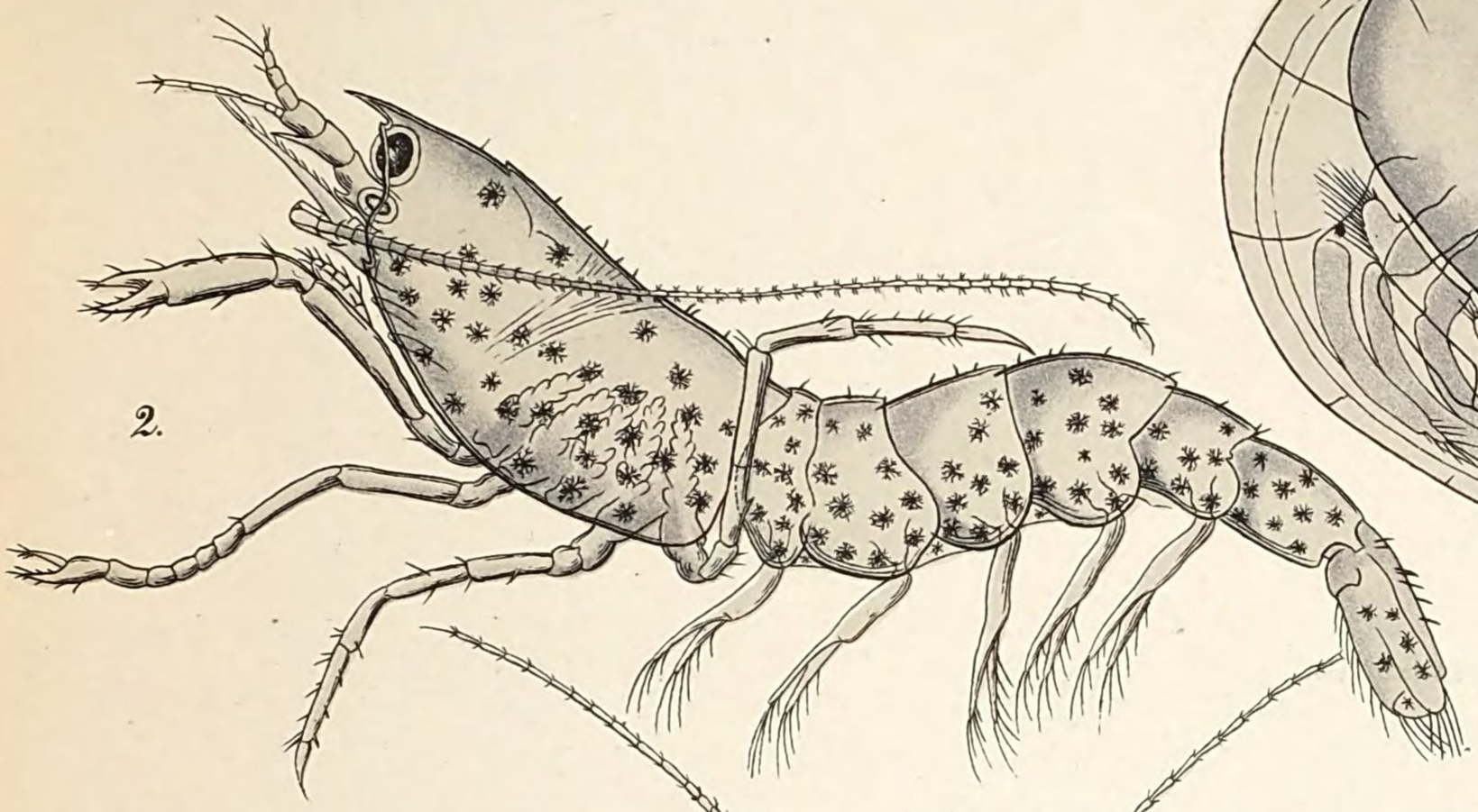
FIG. 7. First maxilliped of the same larva.

FIG. 8. Second maxilliped of the same larva.

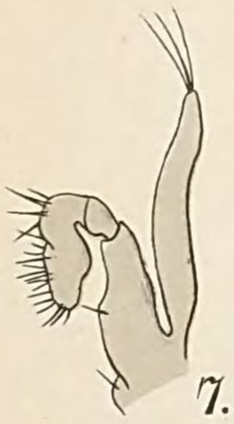
FIG. 9. Third maxilliped of the same larva.



1.



2.



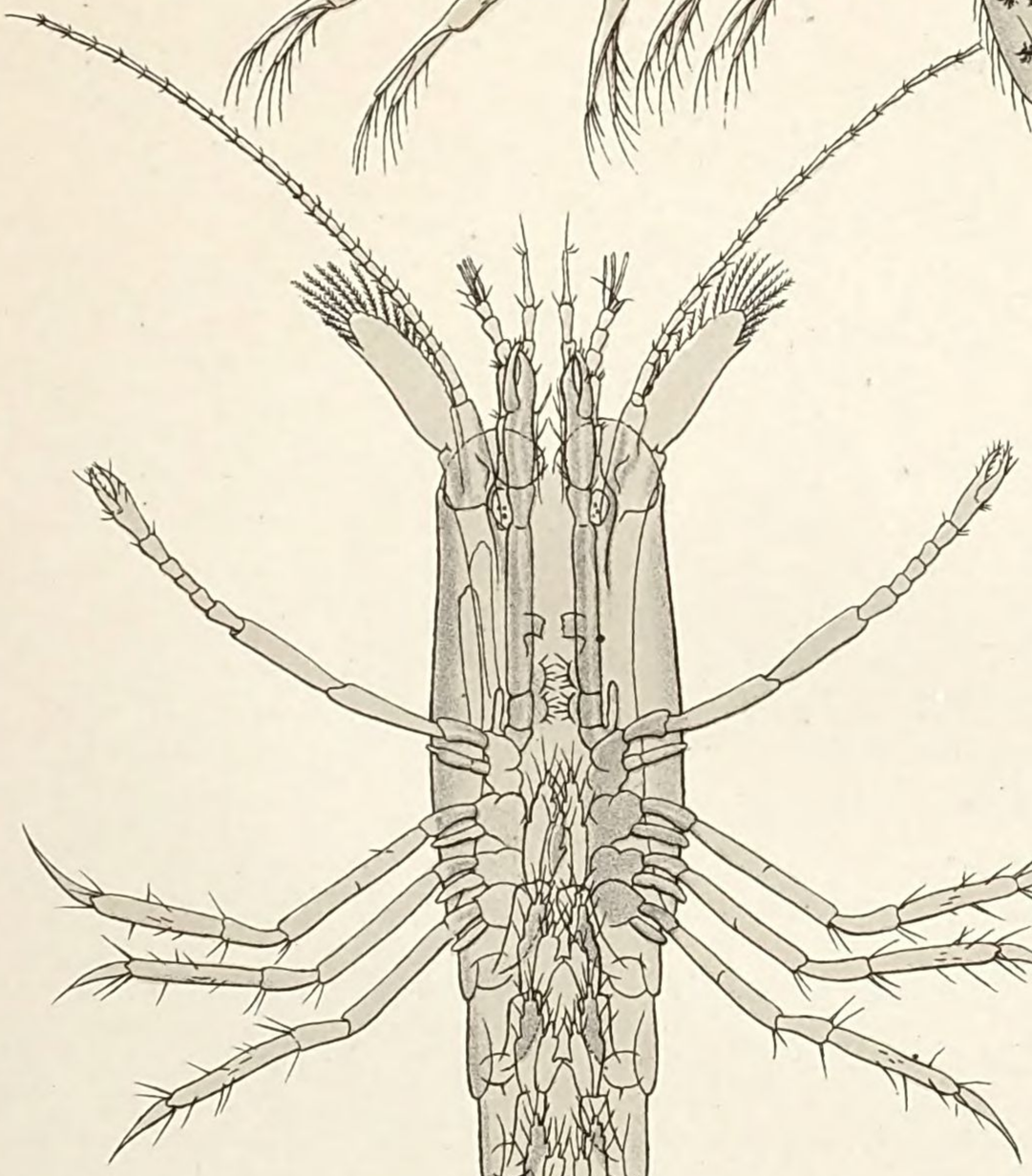
7.

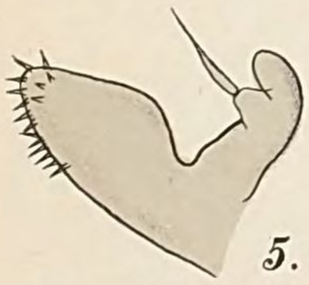


8.

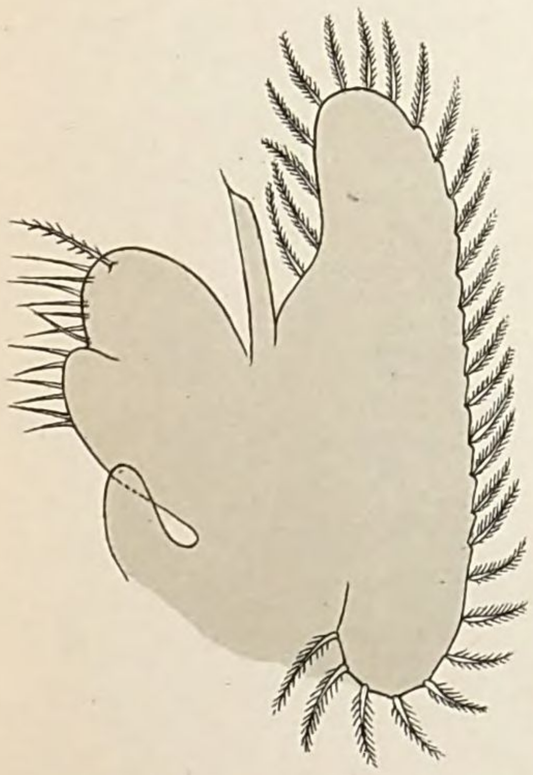


9.

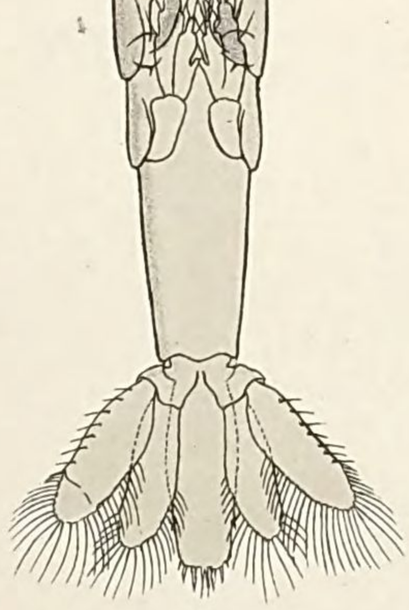




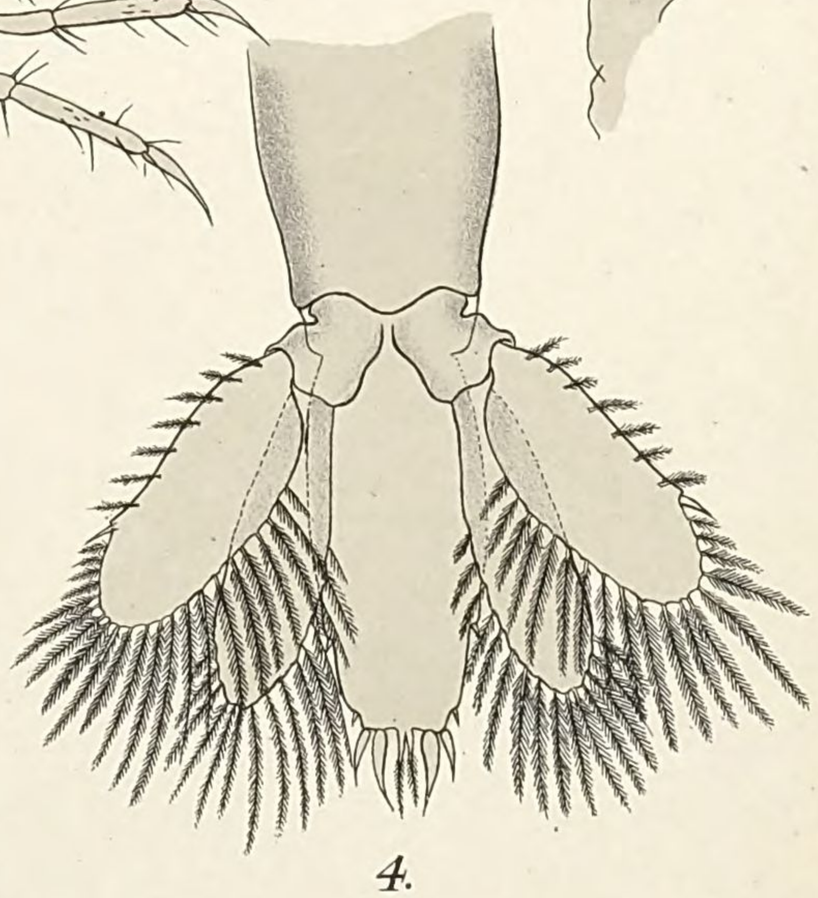
5.



6.



3.



4.

W.K. Brooks, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

Plate XXI.

Fig. 1. First larva of *Alpheus saulcyi*, var. *brevicarpus*, from "loggerhead" sponge. Hatched at 4 p. m., June 10, 1887. A small amount of unabsorbed food yolk remains in the stomach. ×26.

Fig. 1*a*. Line to indicate length of larva. L.=3.5^{mm}.

Fig. 2. Second larva of same, from brood hatched on evening of June 8. Food yolk nearly absorbed. About twenty-four hours old. ×26.

Fig. 2*a*. Line to show length of larva. L.=4^{mm}.

Fig. 3. Head of young from same brood. Four days old. ×52.

Fig. 4. Right first pereiopod of larva of *A. saulcyi*, var. *brevicarpus*, before the molt preparatory to stage shown in Fig. 1. Seen from inner side. ×52. Swimming hairs of exopodites rudimentary.

Fig. 5. Egg embryo of *A. saulcyi*, var. *longicarpus*, nearly ready to hatch. The large chela of the left first pereiopod is conspicuous below the antennæ. ×46.

Fig. 5*a*. To show natural size of the same. Slightly too large. Dimensions: $\frac{4}{100} \times \frac{6}{100}$ inch.

Fig. 6. First and second maxilla of first larva (Fig. 1) before preparatory molt. The parts are gloved with the embryonic skin, which is usually cast off at the time of hatching. ×227.

Fig. 7. Left first pereiopod of same, seen from inner side. ×52.

Fig. 8. Third larva of *Alpheus saulcyi*, var. *brevicarpus*. From same brood as second larva, Fig. 2. Not over twenty-eight hours old. Food yolk not wholly absorbed. ×26.

Fig. 9. Telson and rudimentary uropods, seen from below. ×52.

1.

Fig. 1a.

2.

Fig. 2 a.

3.

4.

5.

6.

7.

Fig. 5 a.

8.

9.

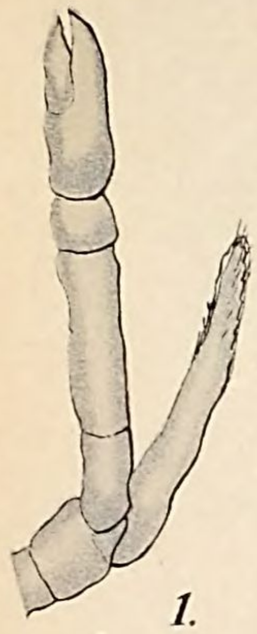
F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS SAULCYI

PLATE XXII.

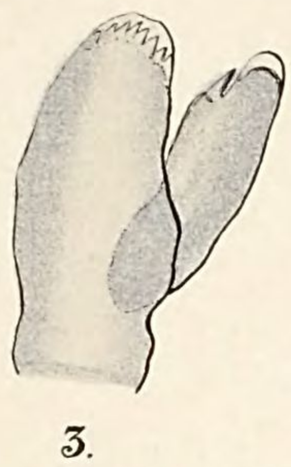
FIG. 1. Left second pereiopod of first larva of *A. saulcyi*, var. *brevicarpus*, from inside. ×64.
FIG. 2. Left third pereiopod of same, from inside. ×64.
FIG. 3. First maxilla of first larva of *A. saulcyi* from brown sponge. ×255.
FIG. 4. Left second abdominal appendage of first larva of *Alpheus saulcyi*, var. *brevicarpus*. ×64.
FIG. 5. Left first abdominal appendage of the same. ×64.
FIG. 6. Rostrum of the same, seen from above. ×64.
FIG. 7. Right second antenna of the same, seen from below. ×64.
FIG. 8. Right first antenna of the same, seen from above. ×64.
FIG. 9. Second antenna of young of *Alpheus saulcyi*, var. *brevicarpus*, six and a half days old. ×64.
FIG. 10. First antenna of the same. ×64.
FIG. 11. Head of male of *Alpheus saulcyi*, var. *longicarpus*, from "loggerhead" sponge. Median spine of rostrum wanting. Drawn from life. L.=5.5^{mm}. ×31.
FIG. 12. Mandible of first larva of *A. saulcyi*, var. *brevicarpus*. ×255.
FIG. 13. Left second antenna of male of *A. saulcyi*, seen from below. No. 8 of Table I, p. 385. ×33.
FIG. 14. Left second antenna of female of *A. saulcyi*. From No. 9 of Table I. ×33.
FIG. 15. Small chela of larva of *A. saulcyi*, var. *brevicarpus*, shown in Fig. 17, at time of hatching. Compare this with the same appendage of the adult. ×64.
FIG. 16. First pereiopod (small chela) of young of *A. saulcyi*, var. *brevicarpus*. From green sponge. Compare this with Fig. 3, Pl. XXIV. ×64.
FIG. 17. Front of a larva of *A. saulcyi*, var. *longicarpus*, which was hatched April 25. Drawn under pressure; eyes slightly distorted. Equivalent to the ordinary third larva, Fig. 8, Pl. XXI. ×64.
FIG. 18. Part of stalk of right first antenna of male of *Alpheus saulcyi*, seen from below, showing the aural scale. The median eye is seen on the right, between the basal segments of the antennules. From No. 8 of Table I. ×26.



1.



2.



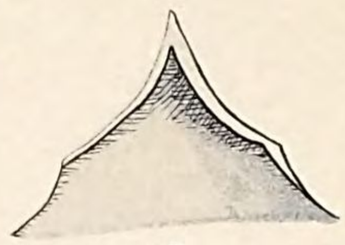
3.



4.



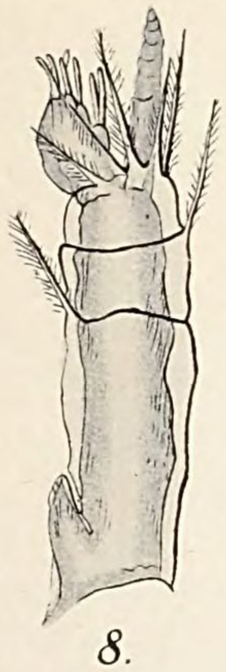
5.



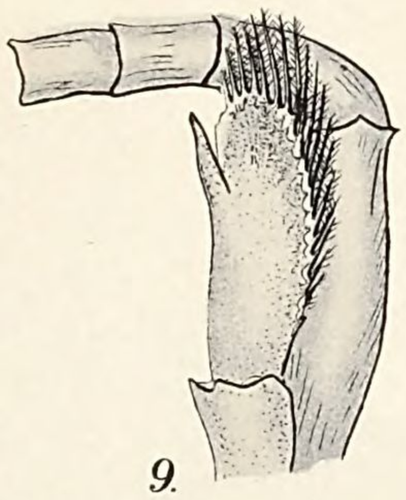
6.



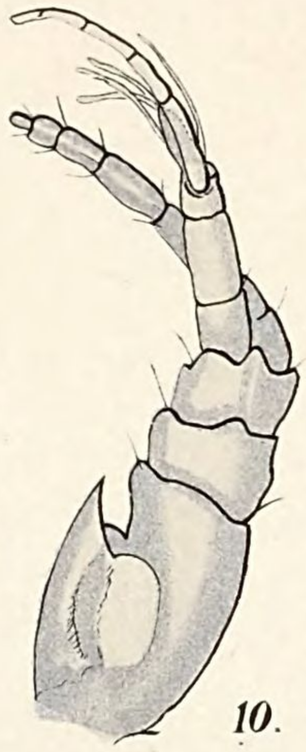
7.



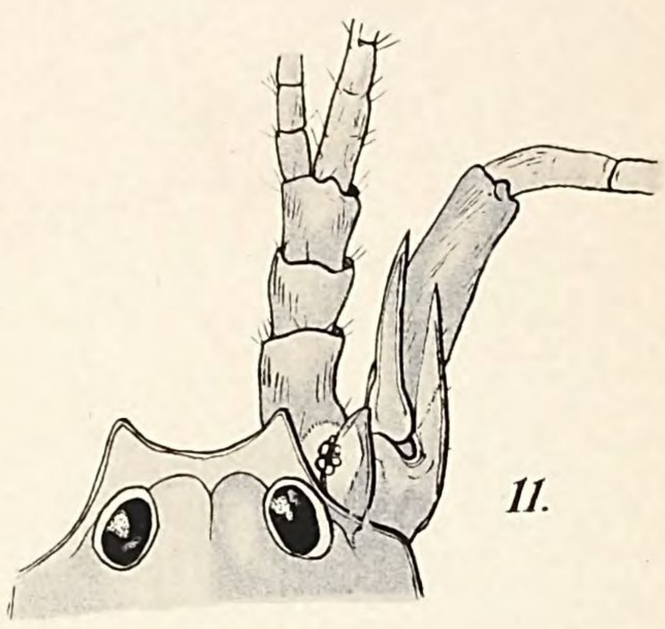
8.



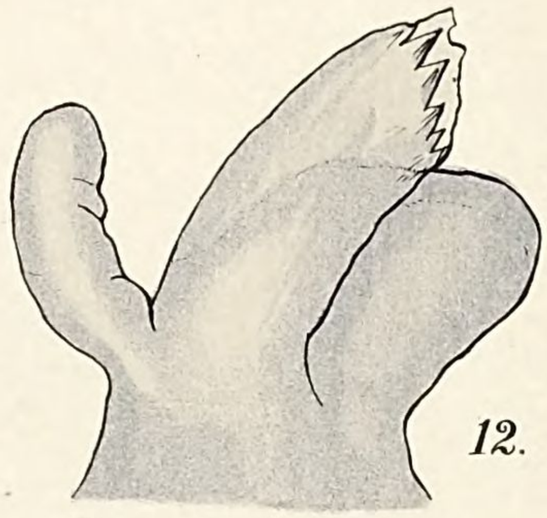
9.



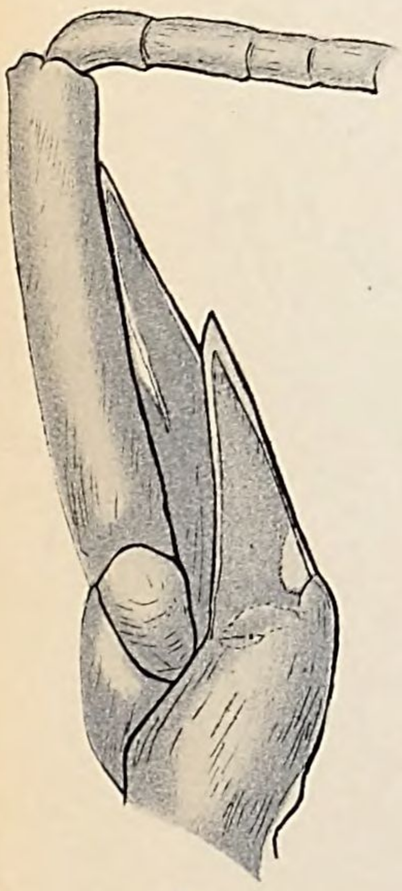
10.



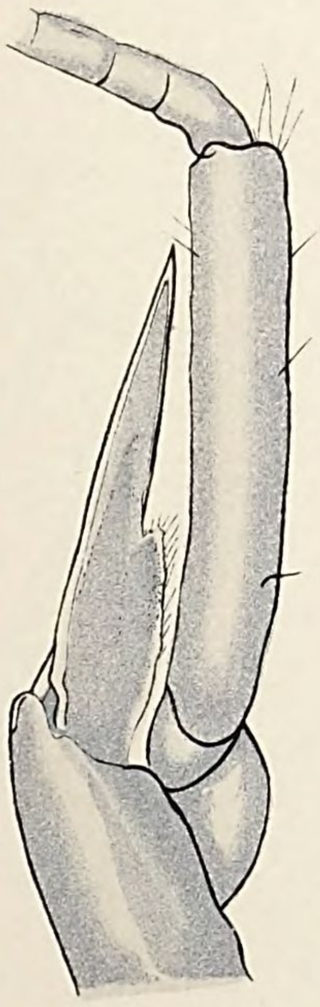
11.



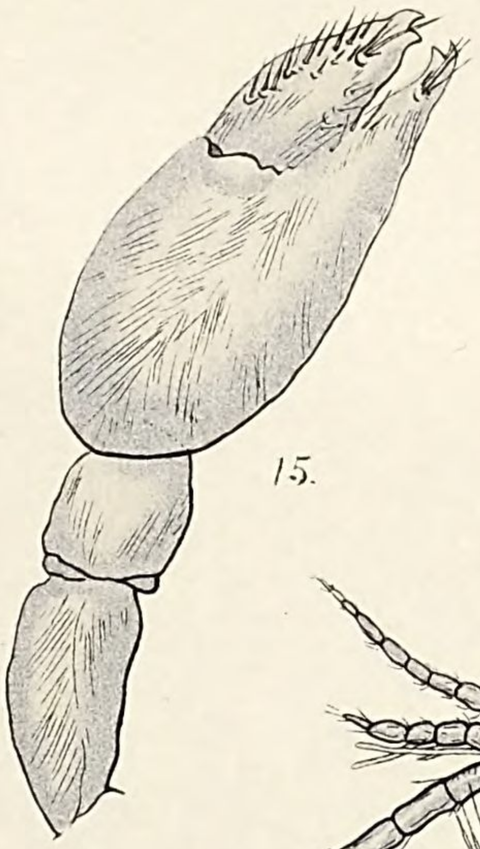
12.



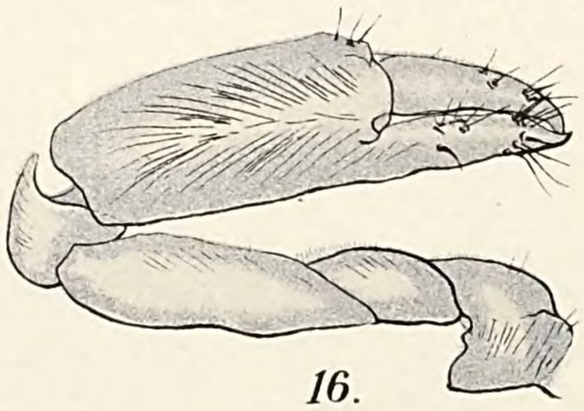
13.



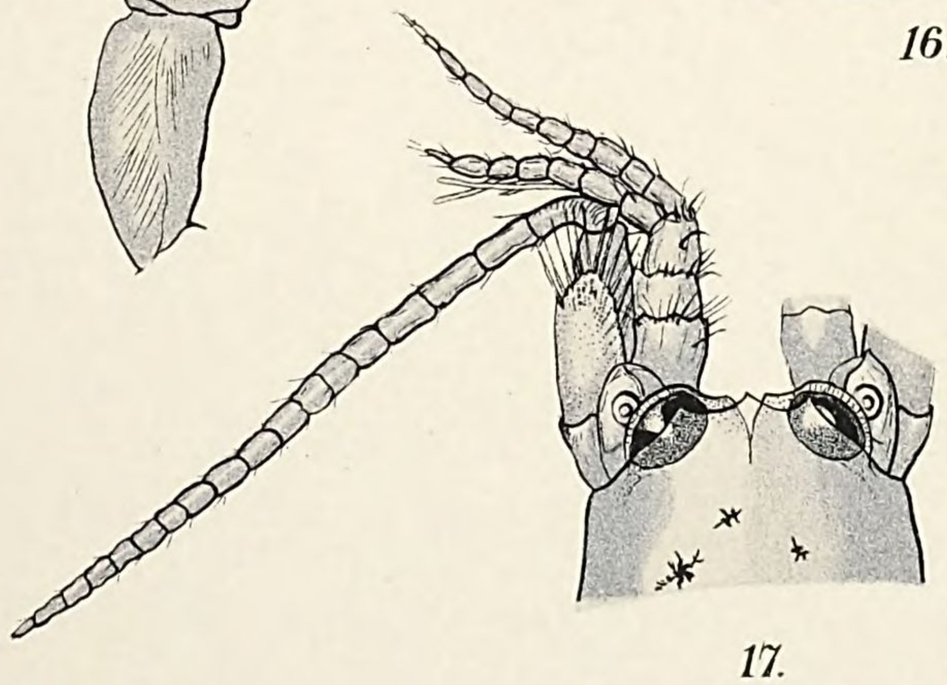
14.



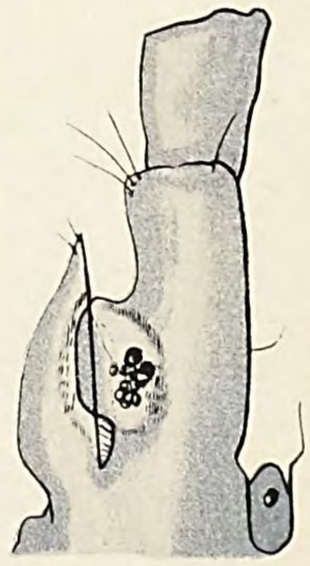
15.



16.



17.



18.

F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS SAULCYI.

Plate XXIII.

Fig. 1. Right second pereiopod of male of *Alpheus saulcyi*, var. *brevicarpus*, seen from the outer side. ×33.
Fig. 2. Terminal segments of right fifth pereiopod of the same. ×33.
Fig. 3. Left mandible of the same, seen from the outer side. ×64.
Fig. 4. Left first antenna, and left compound eye of the same, seen from above. ×33.
Fig. 5. Left third maxilliped of the same, seen from outer side. ×33.
Fig. 6. Right second maxilliped of the same, seen from the outer side. ×64.
Fig. 7. Right first maxilliped, seen from the outer side. ×64.
Fig. 8. Right second antenna of the same, seen from above. ×33.

Fig. 1.

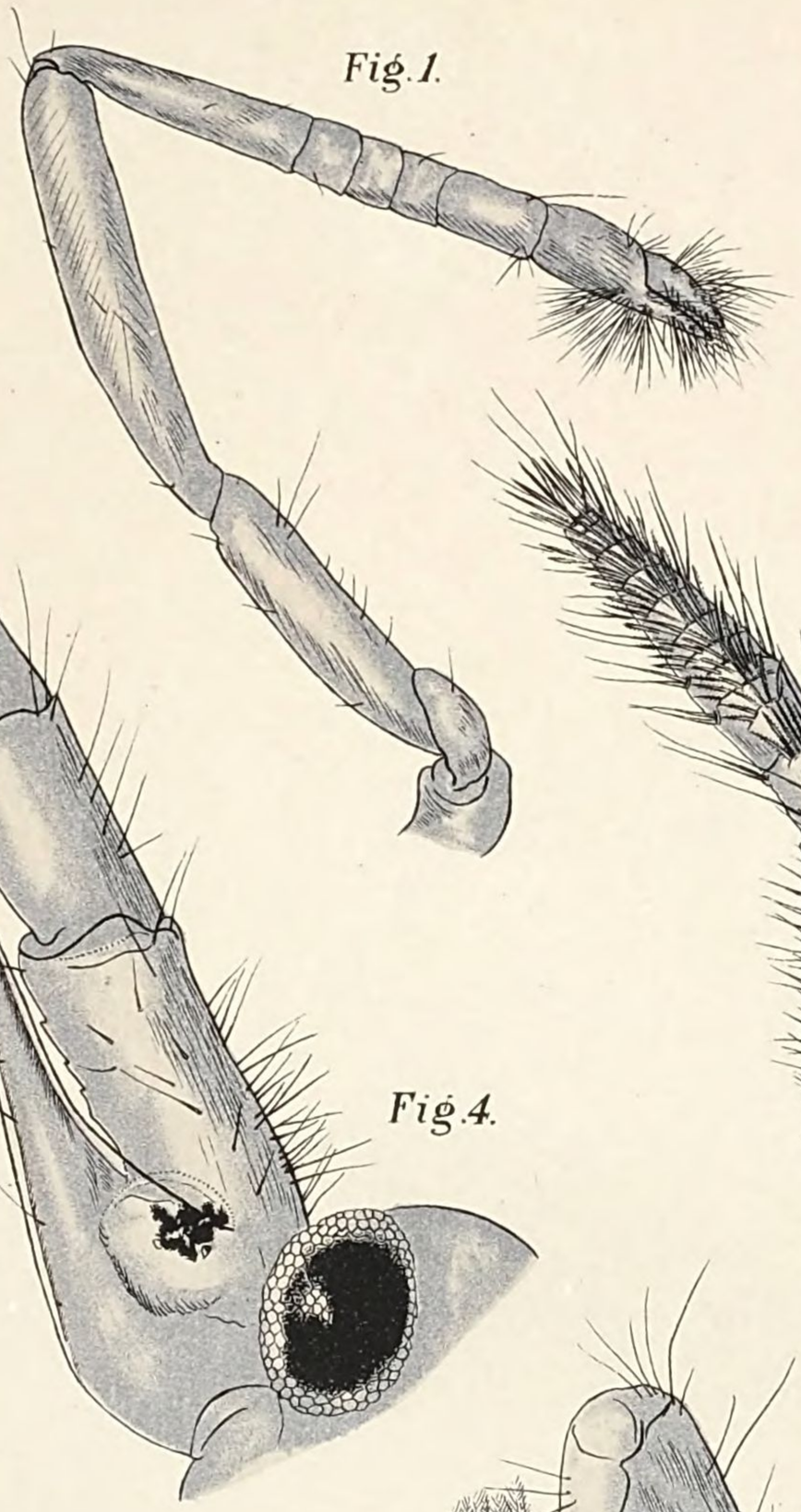


Fig. 2.

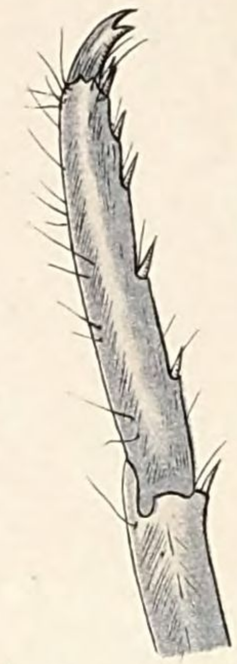


Fig. 3.

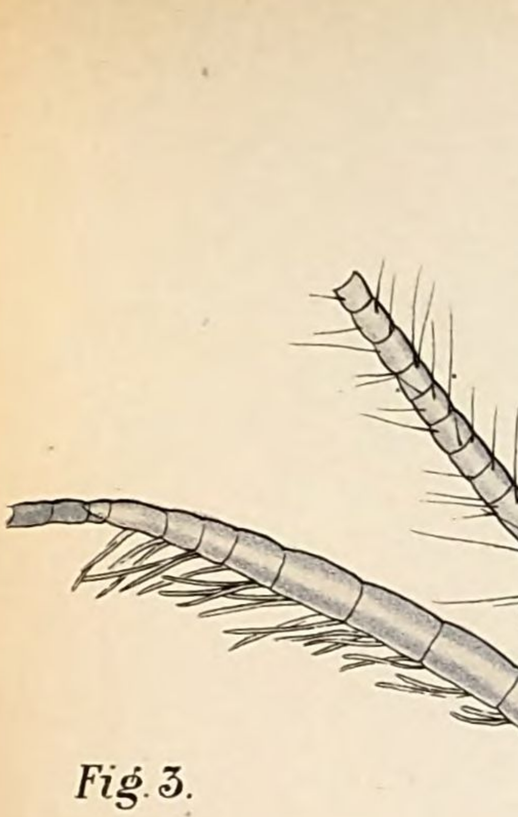


Fig. 4.

Fig. 5.

Fig. 6.

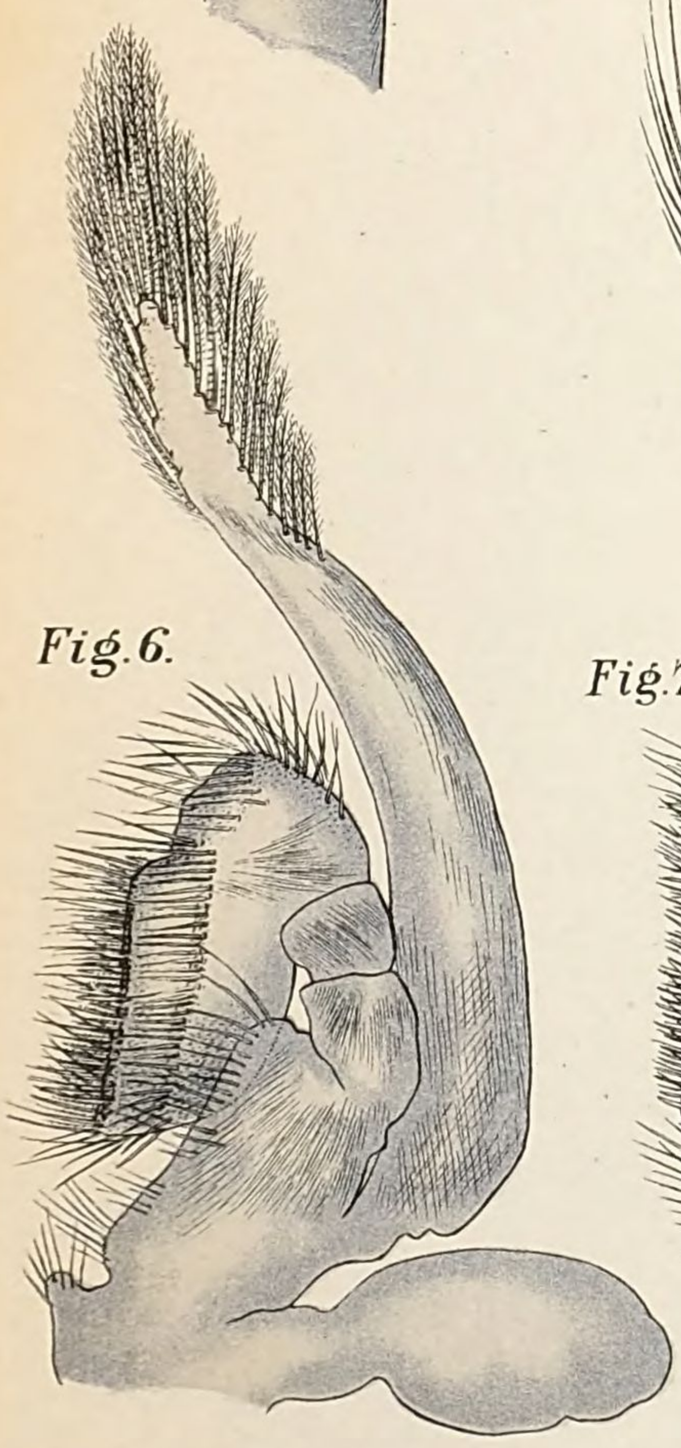


Fig. 7.

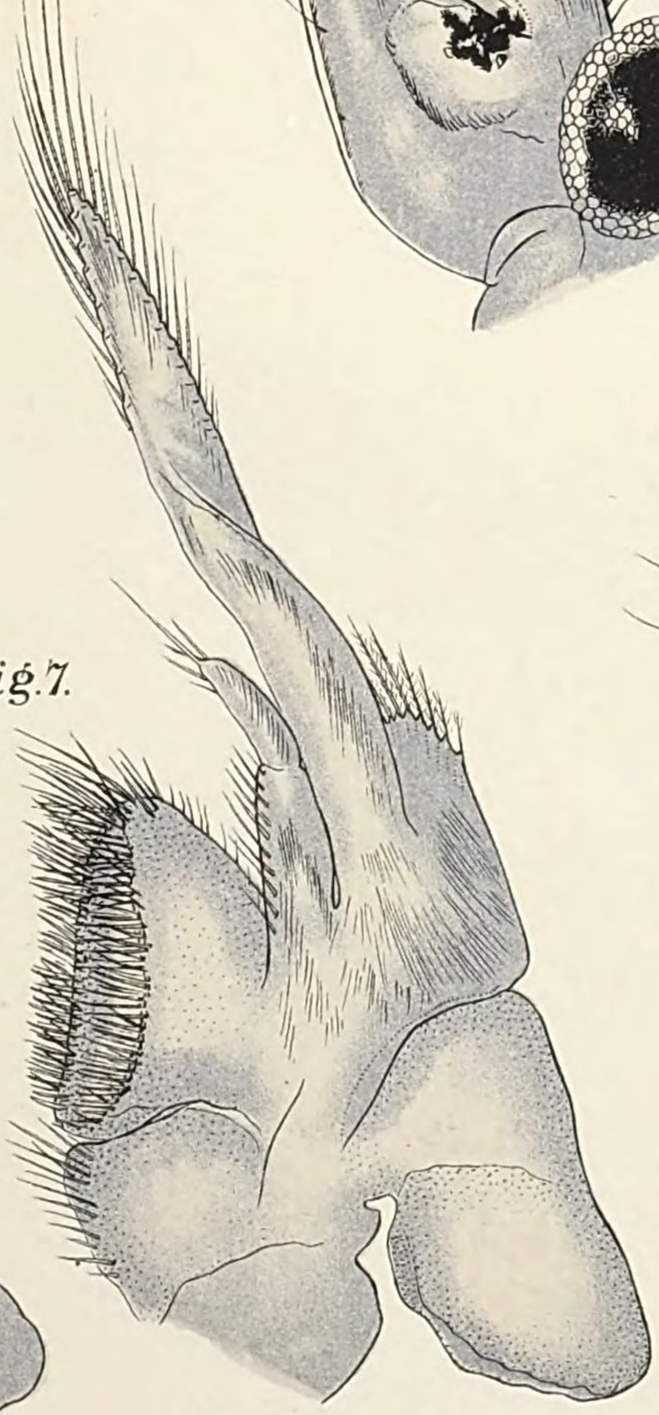


Fig. 8.

F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS SAULCYI.

PLATE XXIV.

FIG. 1. Right fifth pereiopod of male of *Alpheus saulcyi*, var. *brevicarpus*, seen from outer side. ×33.

FIG. 2. Small chela of male of *A. saulcyi*, var. *longicarpus*. From No. 9, Table I. ×33.

FIG. 3. Small chela of male of *A. saulcyi*, var. *brevicarpus*. From No. 8, Table I. Compare with the typical form of the other variety, shown in Fig. 2. ×33.

FIG. 4. First pleopod of male of *A. saulcyi*, from "loggerhead" sponge. ×33.

FIG. 5. Left first pleopod of female of *A. saulcyi*, from "loggerhead" sponge. A single egg is seen, attached to three hairs of the protopodite. The hairs are coated with glue, and the gluey threads are twisted into a chord, which is continuous with a thin sheet of this substance (the membrane of attachment or secondary egg-membrane which envelopes the egg). Below is seen a single hair, from which an egg has broken loose. Drawn from an alcoholic specimen. ×33.

FIG. 6. Right second pleopod of larger female of *A. saulcyi*, showing a number of eggs attached, seen from behind. ×14.

FIG. 7. First maxilla of *A. saulcyi*. Endopodite bent out of position, to a point below the large coxopodite. ×64.

FIG. 8. Large chela of female of *A. saulcyi*, from "loggerhead" sponge. Compare with the *brevicarpus* shown in Pl. IV. ×33.

FIG. 9. Right second maxilla of *A. saulcyi*, seen from outer side. ×64.

Fig. 1.

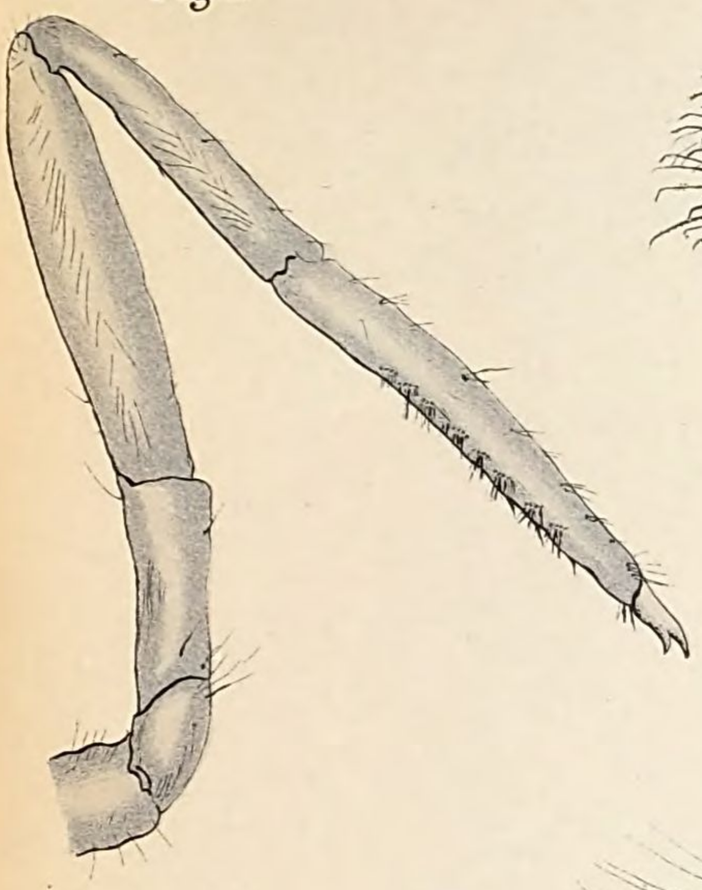


Fig. 2.

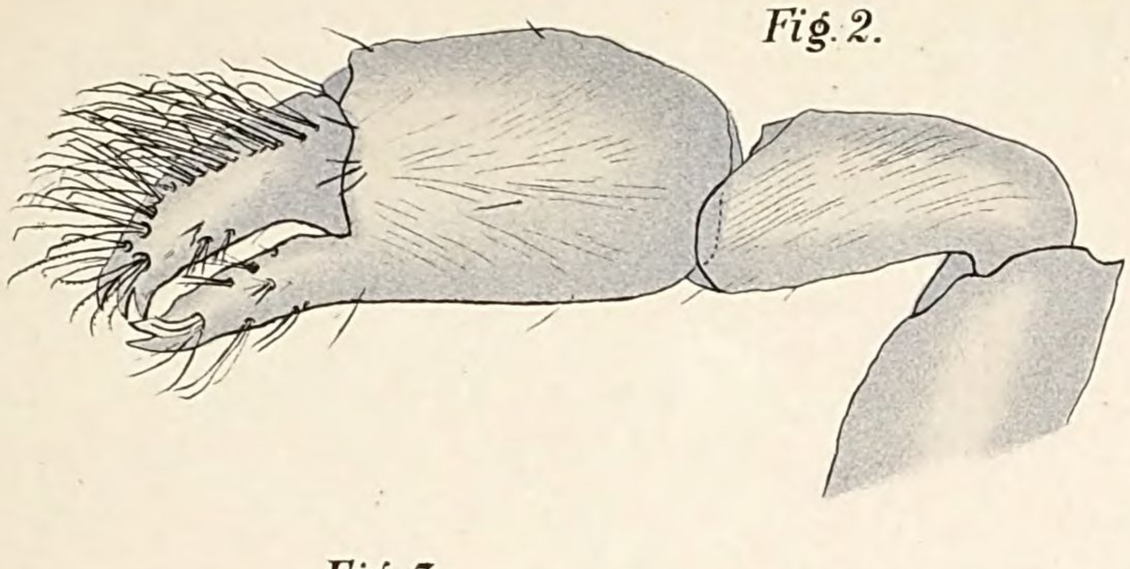


Fig. 3.

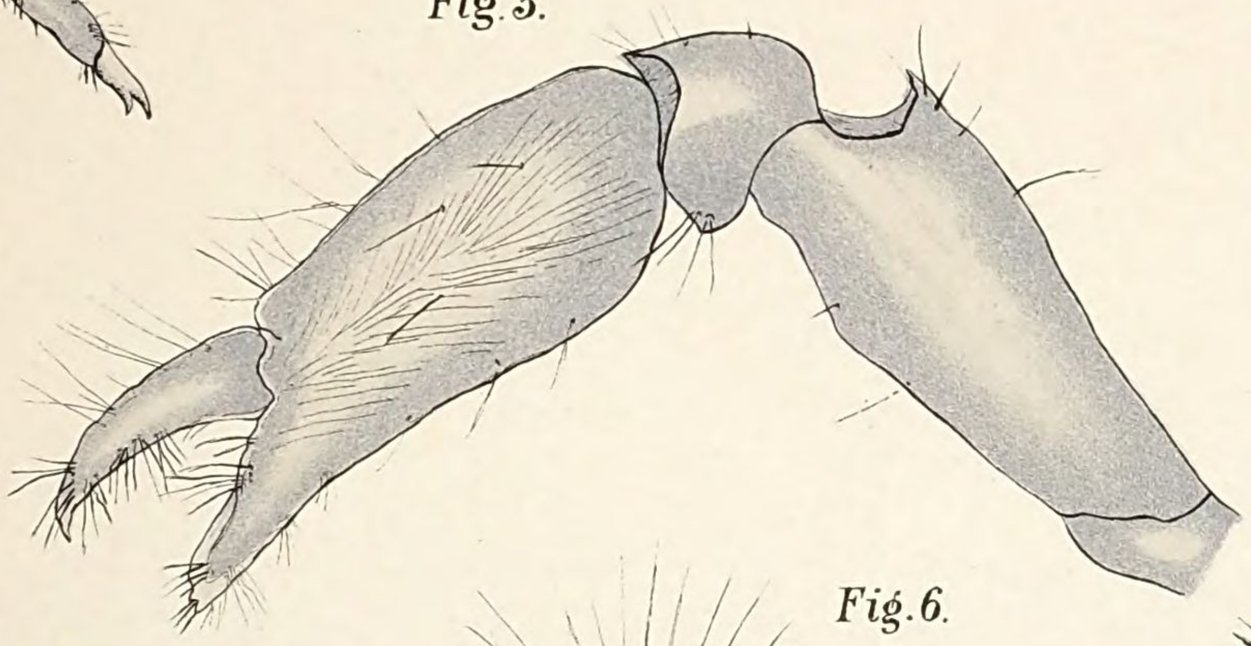


Fig. 4.

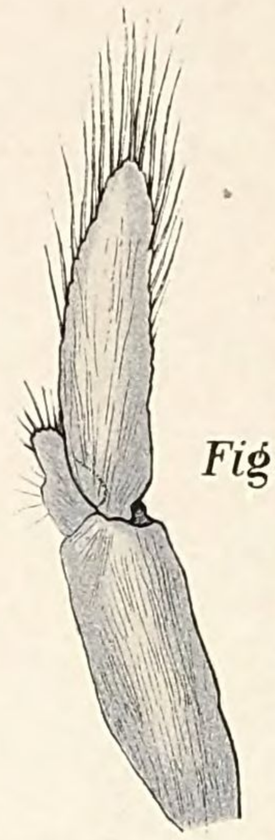


Fig. 5.

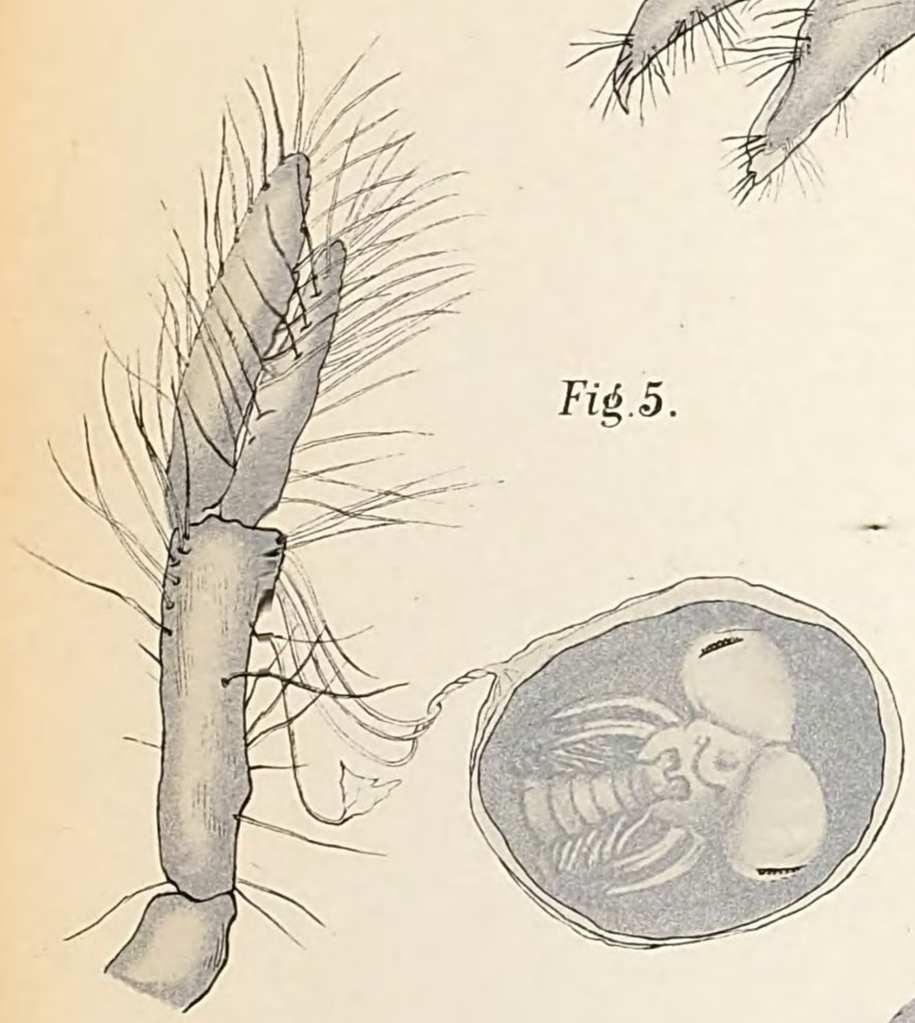


Fig. 6.

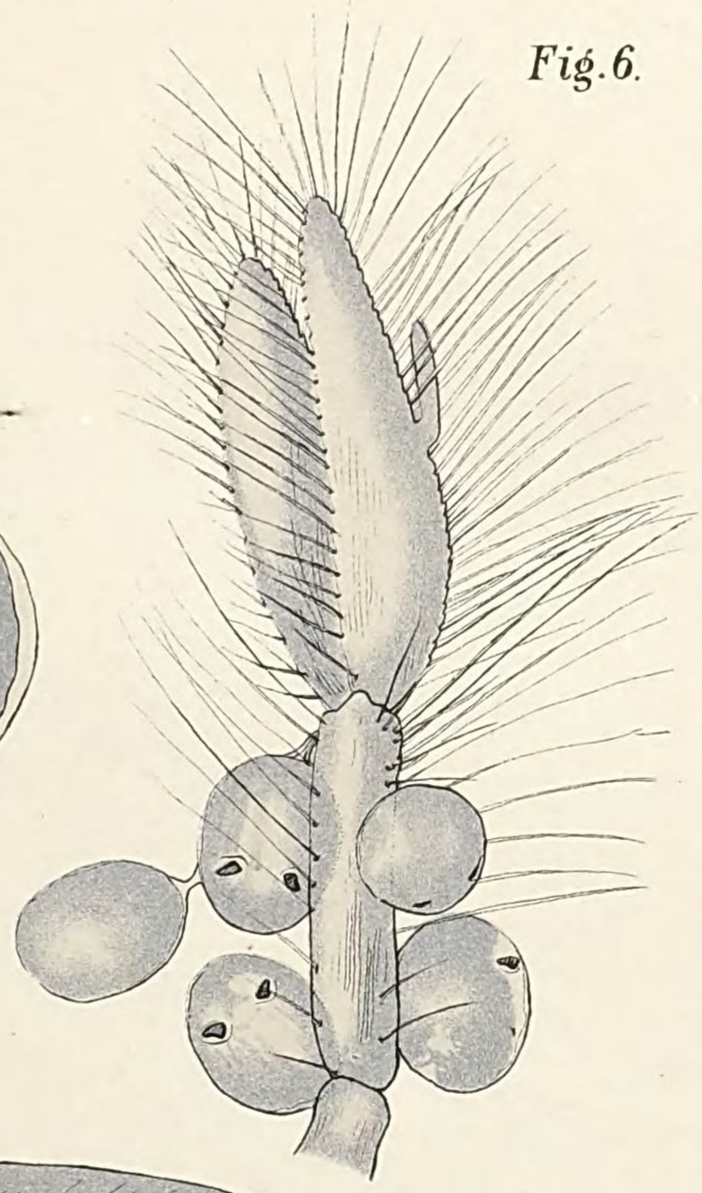


Fig. 7.

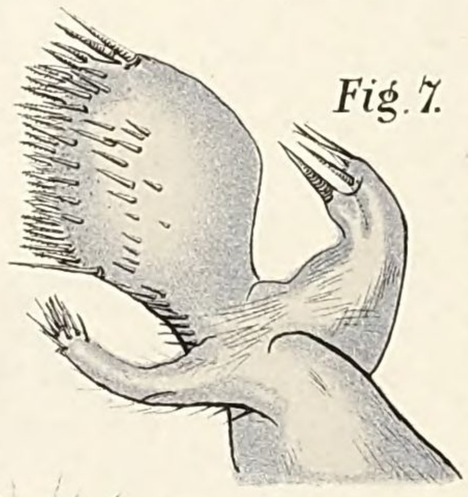


Fig. 8.

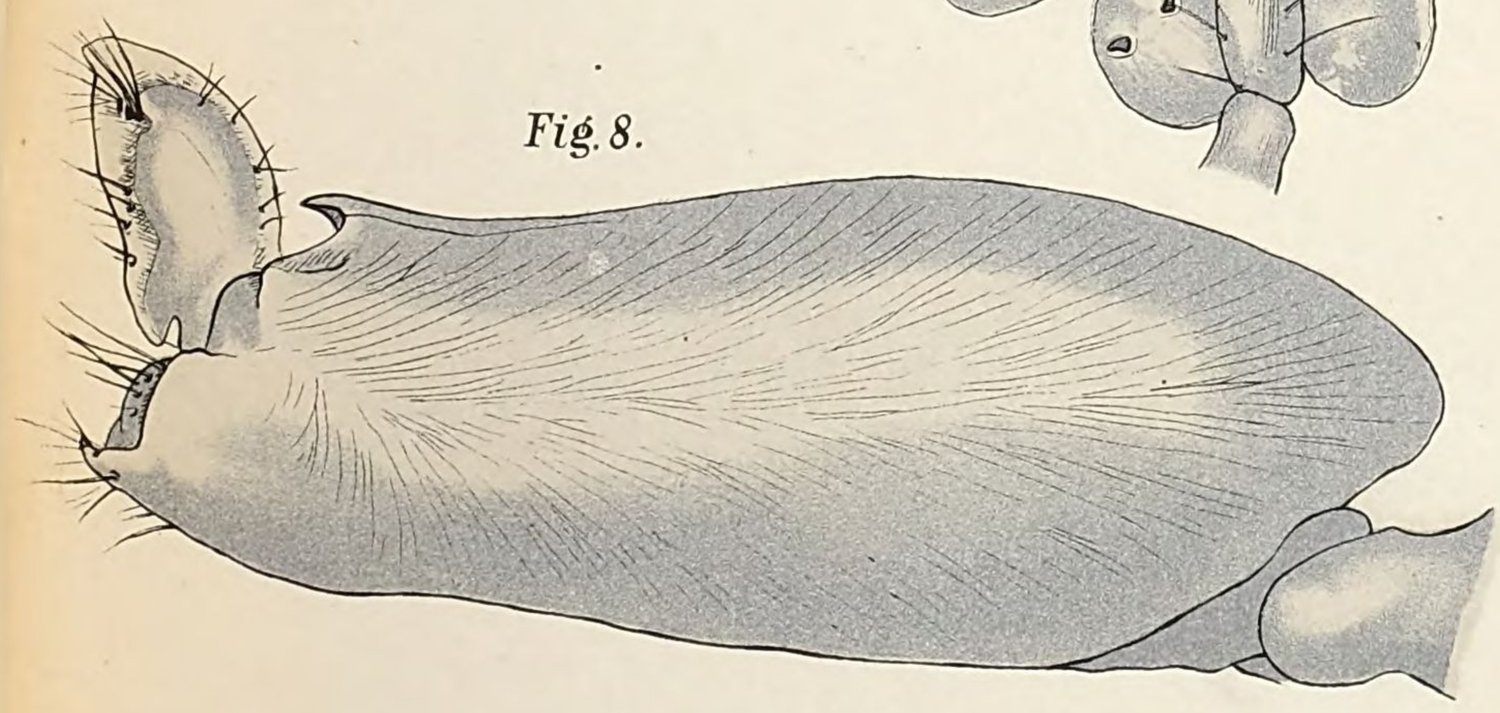
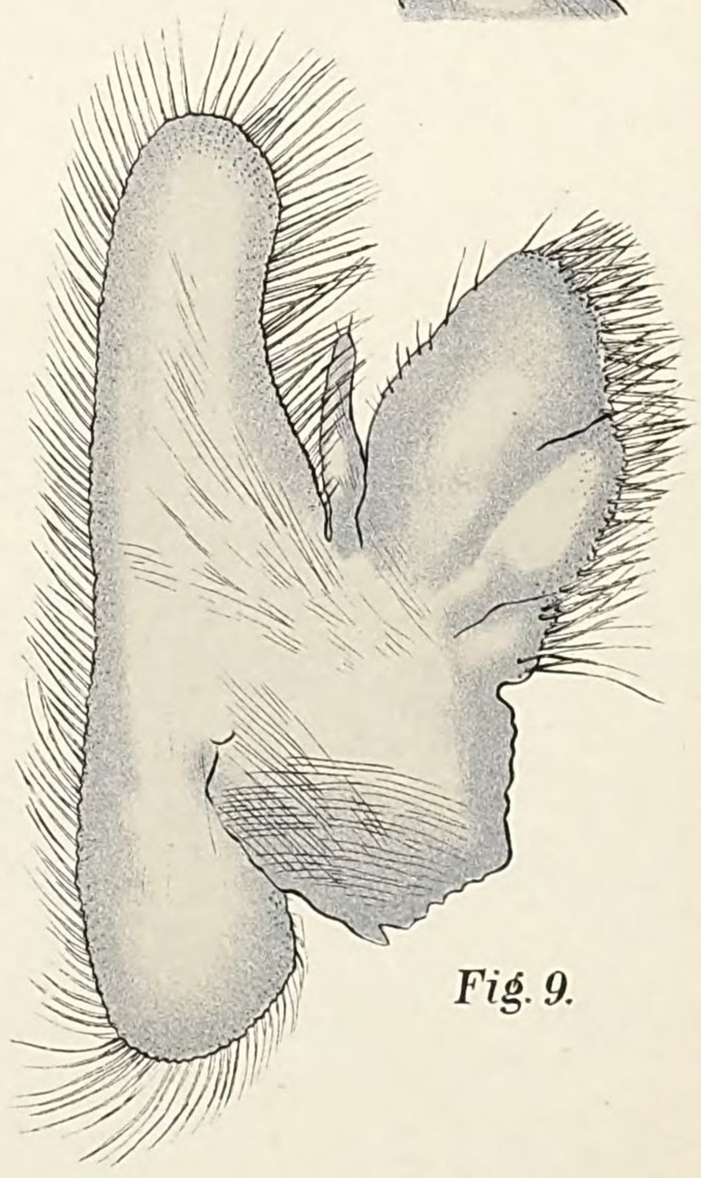


Fig. 9.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS SAULCYI,

PLATE XXV.

FIG. 1. Surface view of segmenting egg of *Hippa talpoides*. Thirty-two yolk pyramids present. ×38.

FIG. 2. Embryo of *Hippa talpoides*, showing optic disks and thoracic-abdominal plate. ×38.

FIG. 3. The central part of a transverse section of the ovary of the lobster, *Homarus americanus*, to show the progressive development of ova; from the same series as that represented, with less enlargement, in Fig. 6. Ovary taken in January. ×281.

FIG. 4. Section of egg of *Hippa talpoides* in yolk segmentation. Sixty-four yolk pyramids present. ×70.

FIG. 5. Part of segmenting egg of *Alpheus minor*, showing a single large nucleus and two smaller nuclei. Compare with Fig. 23. ×281.

FIG. 6. Central portion of transverse section of ovary of the lobster, corresponding nearly to that shown in Fig. 3, showing the germogenal areas and the irregularly radiating blood sinuses. The diameter of the entire ovary is about twice that of the part represented. The largest peripheral ova have an average diameter of about one thirty-third of an inch, and their contents is only about one-eighth that of the ripe egg. ×70.

FIG. 7. Egg-nauplius embryo of *Hippa talpoides*. Appendages appear as simple buds. ×38.

FIG. 8. Post-nauplius stage of *Hippa*. Abdomen bilobed at tip. Buds of at least three pairs of post-mandibular appendages. Figs. 1, 2, 7, and 8 are made from pen-and-ink sketches, and show only the general appearance of the embryo and its relation to the yolk.

REFERENCE LETTERS.

Ab. P., thoracic abdominal plate.
B. C., blood cell.
Bl. S., blood sinus.
Ch., chitinous eggshell.
Ch. W., limiting membrane of blood sinus.
Ct. S., ovarian stroma.
E. f., egg follicle.
F. C., egg follicle.
Ger., germogenal area.
I. E., ovarian stroma (undifferentiated).
o, o^1–o^7, nuclei of ovarian stroma and developing eggs.
O. D., optic disk.
O. L., optic lobe.
Y. P., yolk pyramid.
Y. S., yolk spherule.
Vac., yolk vacuole.

Fig.1.



Fig.2.

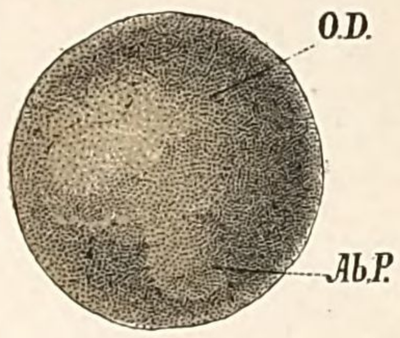


Fig.3.

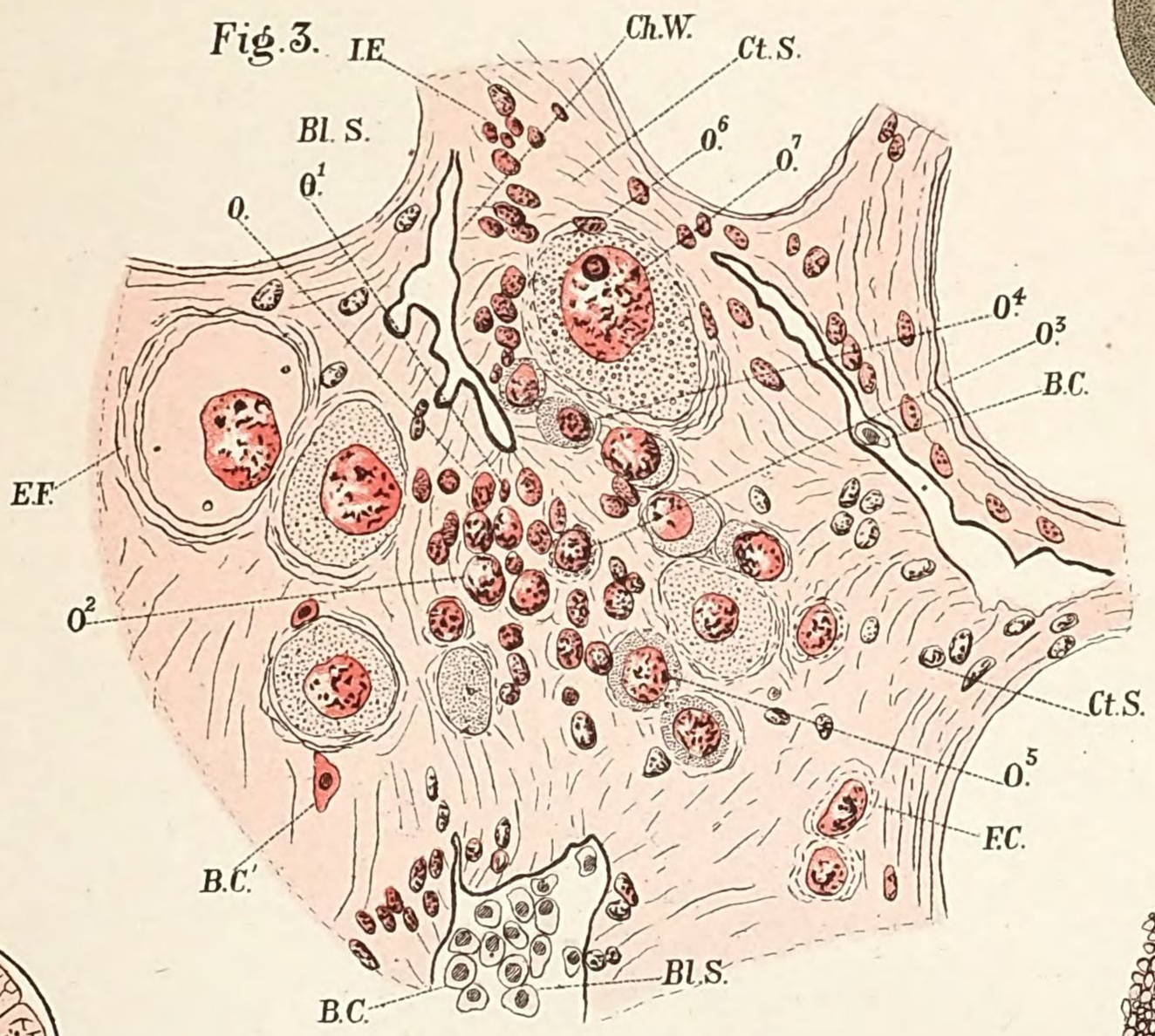


Fig.4.

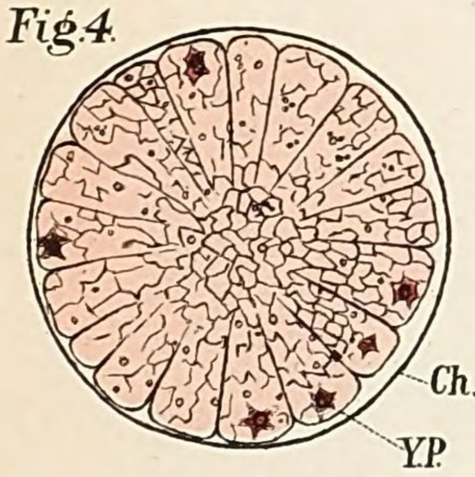


Fig.5.

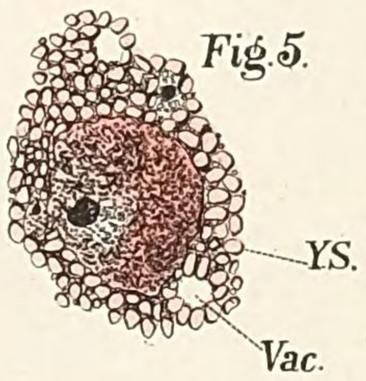


Fig.6.

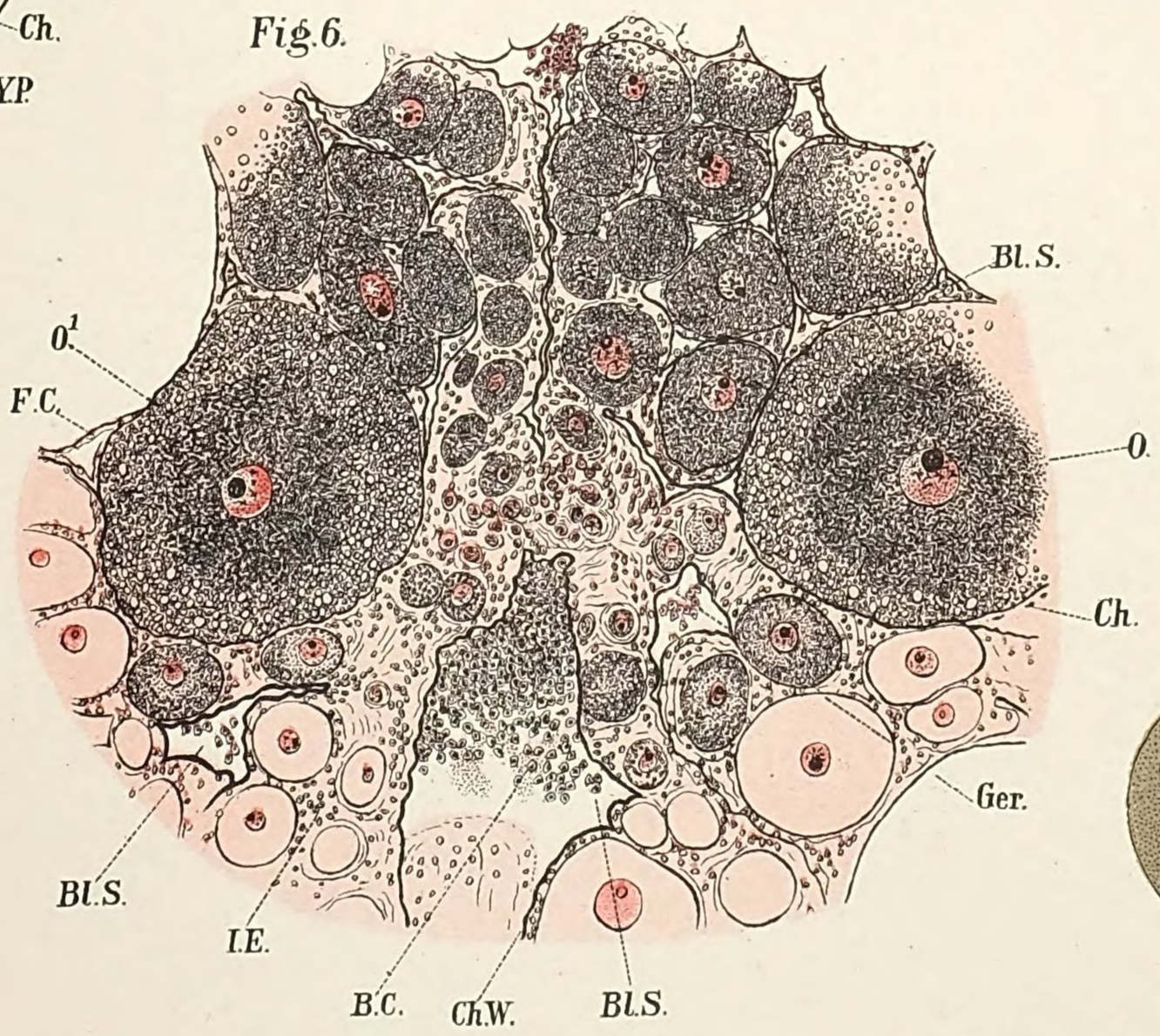


Fig.7

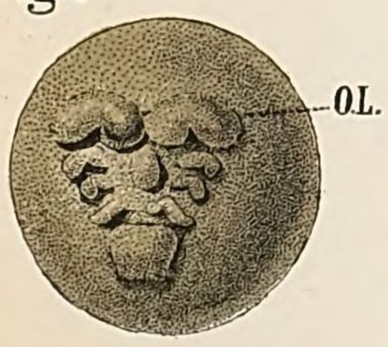
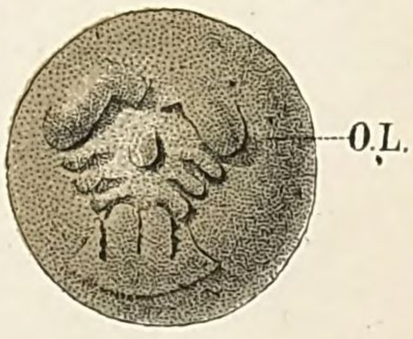


Fig.8.



F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

HIPPA, HOMARUS AND ALPHEUS.

Plate XXVI.

Fig. 9. Section through segmenting egg of *Alpheus saulcyi*. Eight cells present. Yolk unsegmented. Egg membranes diagramatically represented. ×70.

Fig. 10. Surface view of the same. Sixteen cells present. Yolk pyramids formed. The peripheral nuclei are seen through a thin layer of yolk. ×70.

Fig. 11. Transverse section through the immature ovaries of *Alpheus*. Ovary taken in June, from female "in berry." Diameter of largest ovarian egg, one one hundred and sixty-eighth of an inch. Diameter of extruded egg, one fiftieth of an inch. Contents of ovarian egg, one thirty-seventh of that of the extruded egg. ×281.

Fig. 12. Section through segmenting egg of *Alpheus minor*, from Beaufort, North Carolina, showing nests of nuclei. ×70.

Fig. 13. Swarm or nest of nuclei, like those of preceding figure. ×281.

Fig. 14. Section through egg of *Alpheus minor*, cutting segmentation nucleus. Nucleus elongated, with irregular, indefinite boundary. ×70.

Reference Letters.

Al. C., alimentary canal.
B. C., blood cell.
B. S., blood space (possibly unnaturally distended).
Ch., chitinous egg envelopes.
D. A., dorsal aorta.
e, e^1, young ova.
F. E., ovarian stroma.
F. E.[1], follicular epithelium.
F. C., follicular epithelium.
Ger., germogen.
Ger.[1], position of germogen in ovary, with ova nearly ripe.
G. V., germinal vesicle.
O. W., ovarian wall.
SS, swarm of nuclear bodies.
Vac., yolk vacuole.
Vit., vitellogen.
x, cell shown in Fig. 30.
Y. P., yolk pyramid.

Fig.9.

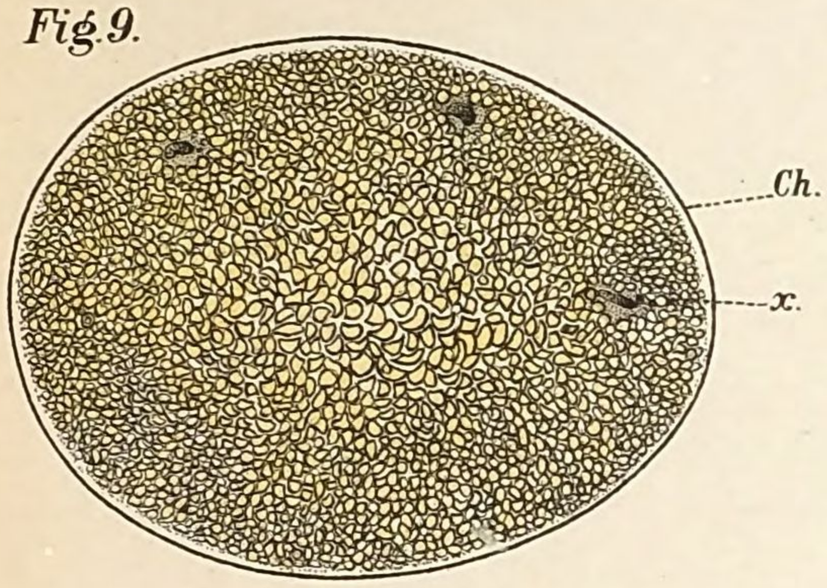


Fig.10.

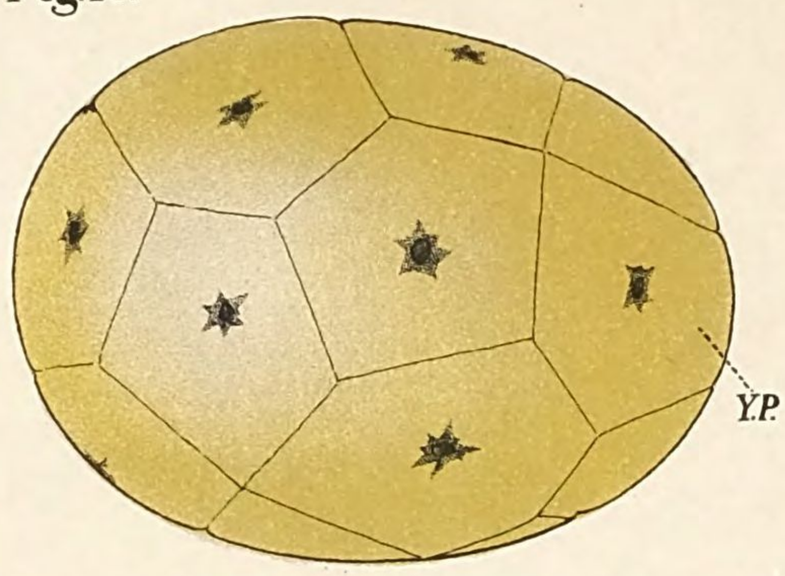


Fig.11.

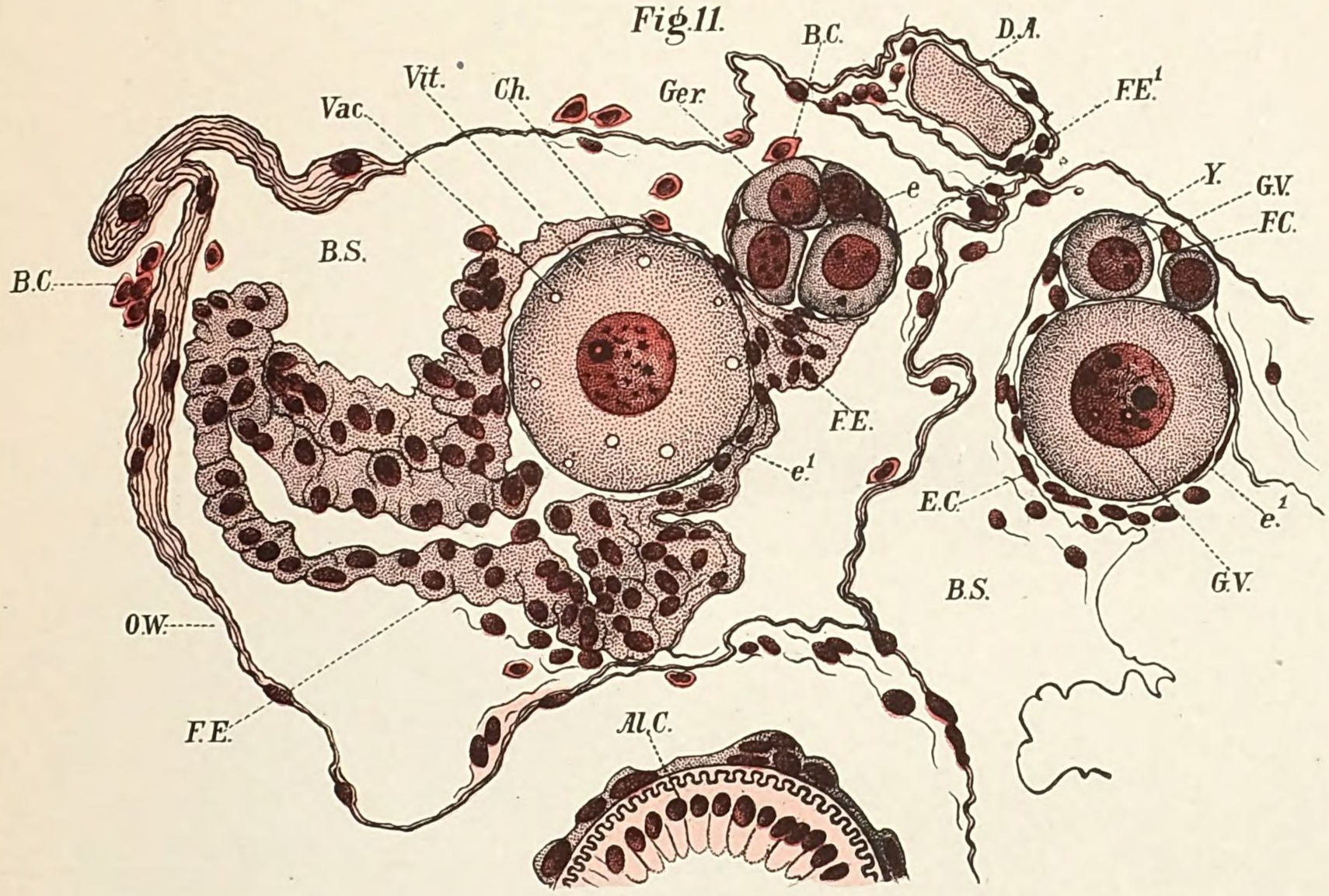


Fig.12.

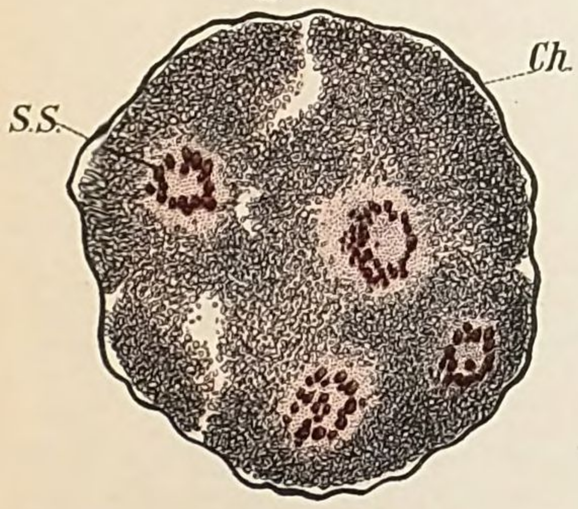


Fig.13.

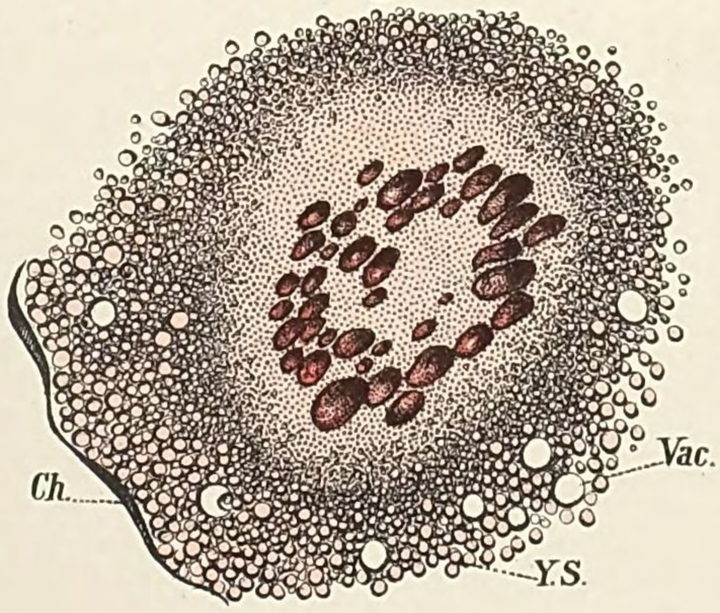
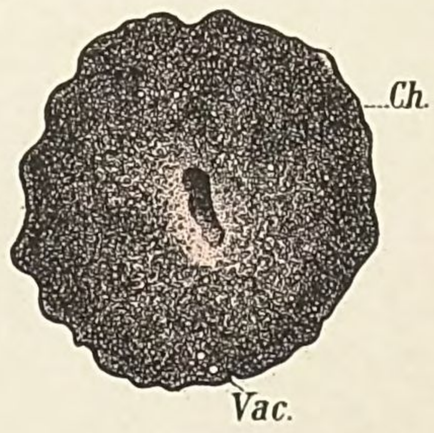


Fig.14.



F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co New York.

ALPHEUS SAULCYI AND A. MINUS.

PLATE XXVII.

FIG. 15. Section of egg of Bahaman variety of *Alpheus heterochelis* in typical yolk pyramid stage Sixty-four cells present. ×70.

FIG. 16. Segmentation nucleus of egg of *A. saulcyi*, nearly central in position. ×277.

FIG. 17. Section of an egg of *A. saulcyi*, which was normally laid but unfertilized, showing the female pronucleus. ×70.

FIG. 18. Degenerating nuclei containing spore-like bodies, from the egg-nauplius embryo, the structure of which is shown in Pls. XLI–XLIII. ×610.

FIG. 19. Blood cells of adult Alpheus. ×610.

FIG. 20. Endodermal cells from the ventral wall of the primitive alimentary cavity of *Astacus fluviatilis*. After Reichenbach (54) Taf. VIII, Fig. 67. This is taken from the egg-nauplius stage to show the origin of "secondary mesoderm." The elements here marked m^1, *k* are described as cells which have originated from the endoderm, and completed their metamorphosis into ordinary mesoderm cells. These may be compared directly with *b*, FIG. 18, and *s*, s^2, Fig. 21, from the egg-nauplius of *Alpheus saulcyi*, and are rather to be regarded as nuclear bodies in the earlier stages of *retrogressive* metamorphosis. ×256.

FIG. 21. Part of transverse section through the foregut of the egg-nauplius of *Alpheus saulcyi*, to show the degenerative cell products. ×610.

REFERENCE LETTERS.

A. Y. S., altered food-yolk.
Ch., chitinous egg membranes.
ec., ectoblast.
i., nuclear body, with vesicular chromatin mass.
k, k^1, *l*, *m*, m^{1-3}, nuclear products in yolk.
Mes., mesoblast.
N., $N.^1$, nuclei of entoblastic cells.
n., nucleolus of entoblastic cell (not clearly shown).
Ol., oil drop.
Ret., protoplasmic reticulum.
S, *s*, s^2., degenerative products.
Sep., cleavage plane.
Std., foregut.
Vac., yolk vacuole.
Y., yolk.
Y. P., yolk pyramid.
Y. S., yolk sphere.

Fig.15.

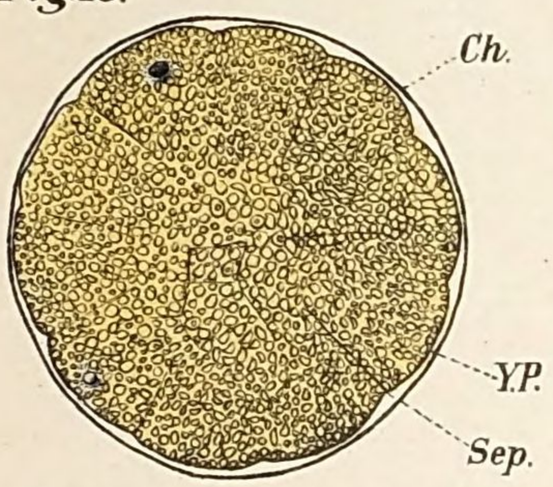


Fig.16.

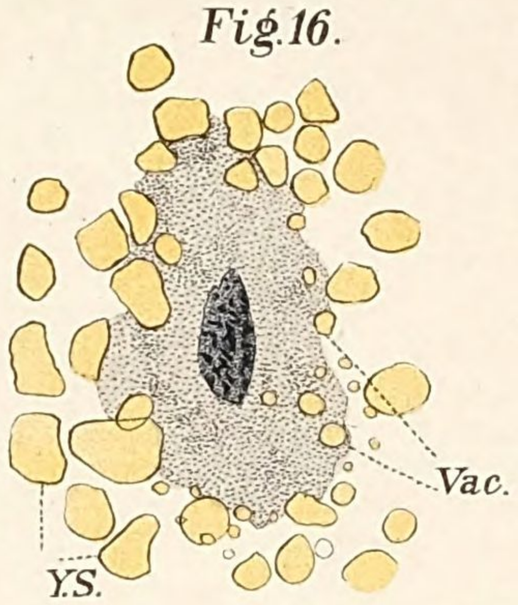


Fig.17.

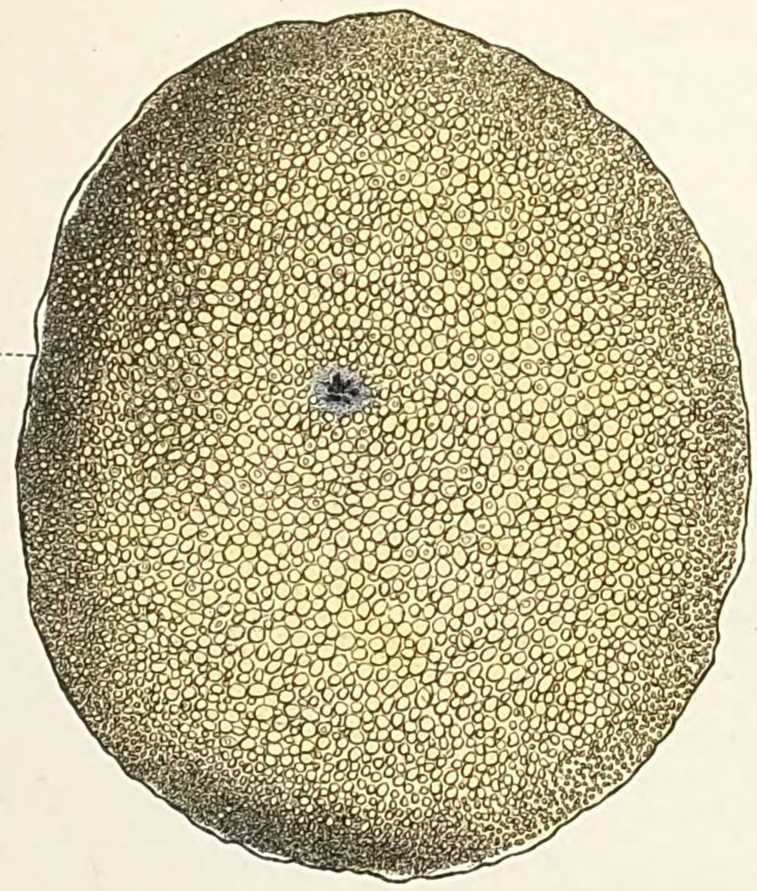


Fig.18.

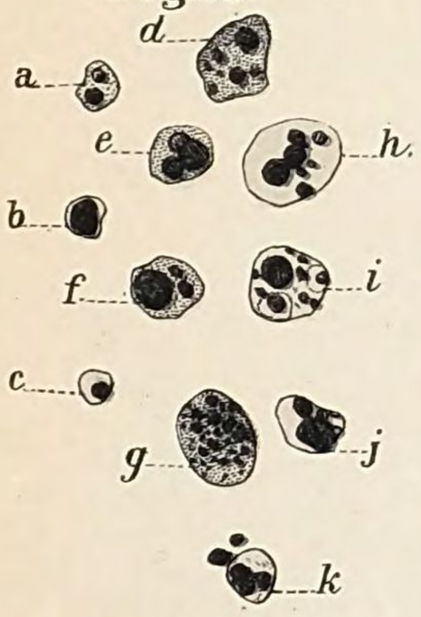


Fig.19.

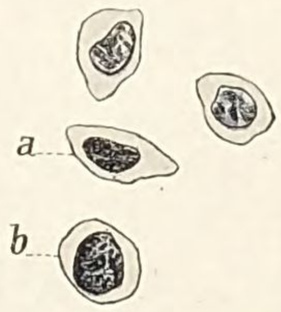


Fig.20.

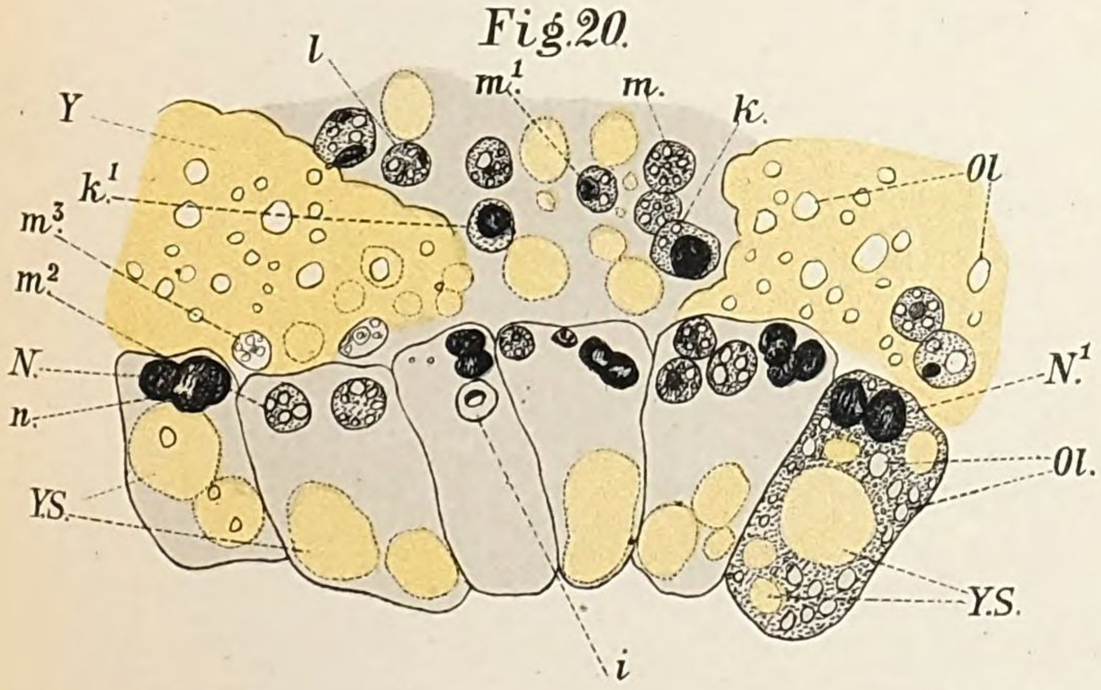
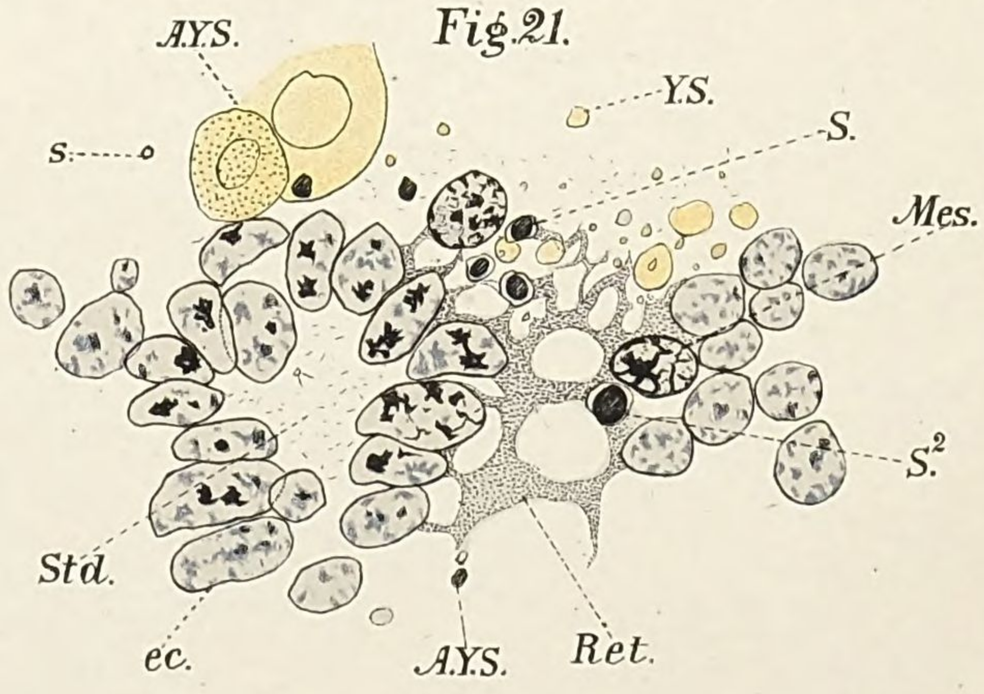


Fig.21.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS AND ASTACUS.

PLATE XXVIII.

FIG. 22. Part of section of segmenting egg of *Alpheus minor* from Beaufort, North Carolina, showing nuclear body in clear area. ×277.

FIG. 23. Swollen, probably degenerating, elements, from segmenting egg of *A. minor*. ×277.

FIG. 24. Section through base of yolk pyramid of egg of *Palæmonetes vulgaris*. About sixty-four cells present. ×277.

FIGS. 25, 26. Two successive sections through clear area in segmenting egg of *Alpheus minor*, showing degenerative products and nuclear bodies in process of breaking up. ×277.

FIG. 27. Part of section through segmenting egg of *Pontonia domestica*, before cleavage of the yolk. The egg contains three nuclei, one of which is seen to be in karyokinesis. ×277.

FIG. 28. Part of section of an Alpheus egg in same stage as that shown in Fig. 9. Cell dividing indirectly and in horizontal plane. ×277.

FIG. 29. Section of egg of *Alpheus minor*, probably at close of segmentation. ×277.

FIG. 30. Enlarged view of cell *x*, and part of section shown in Fig. 9. ×277.

REFERENCE LETTERS.

Ch., egg membranes.
N., nucleus.
P. A., protoplasmic area.
P. N., perinuclear protoplasm.
SC, SC^{1-6}, degenerating cell products.
Y, yolk.
Y. B., yolk ball.
Y. S., yolk sphere.
Vac., vacuole.

Fig.22.

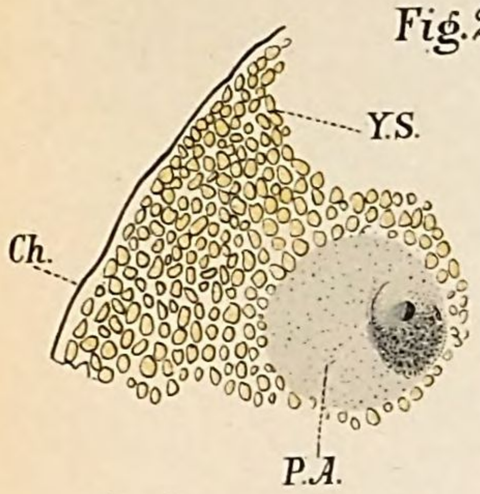


Fig.23.

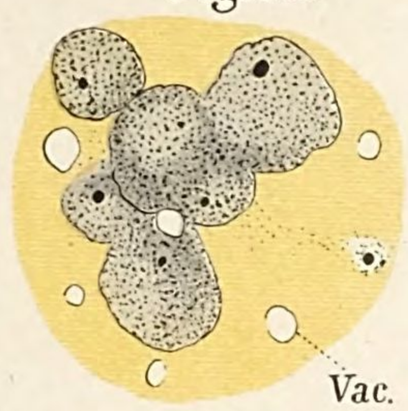


Fig.24.

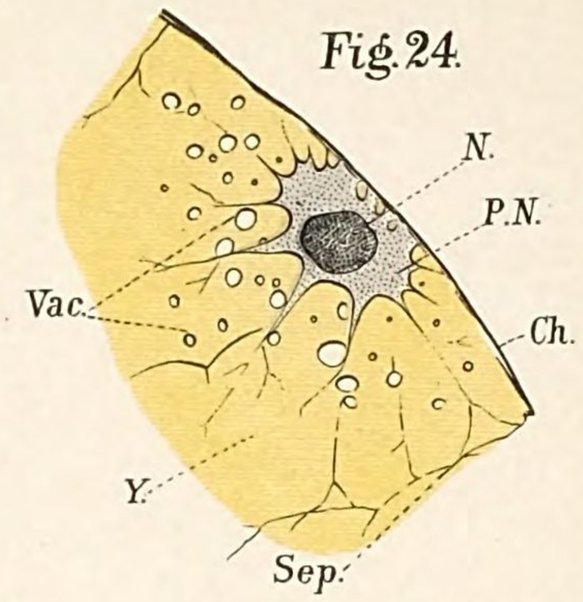


Fig.25.

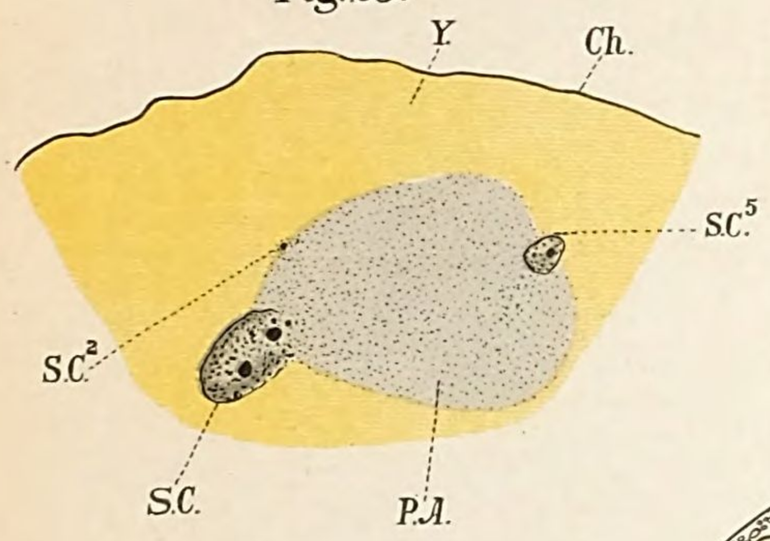


Fig.26.

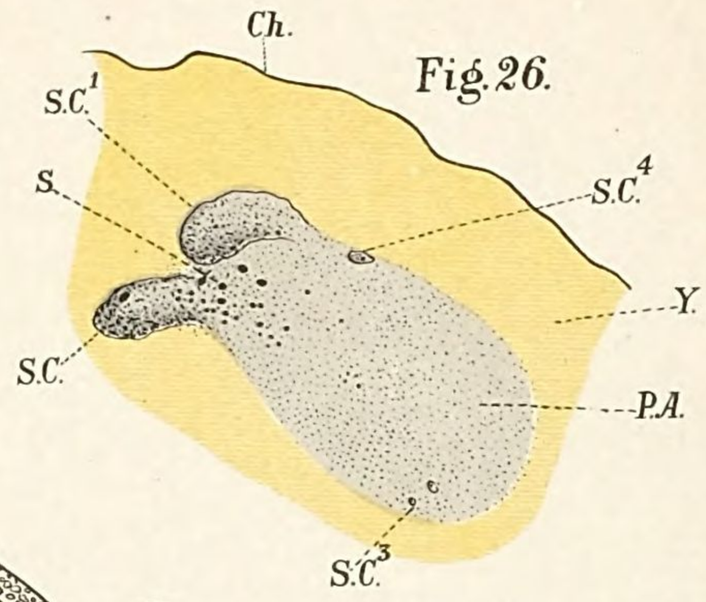


Fig.27.

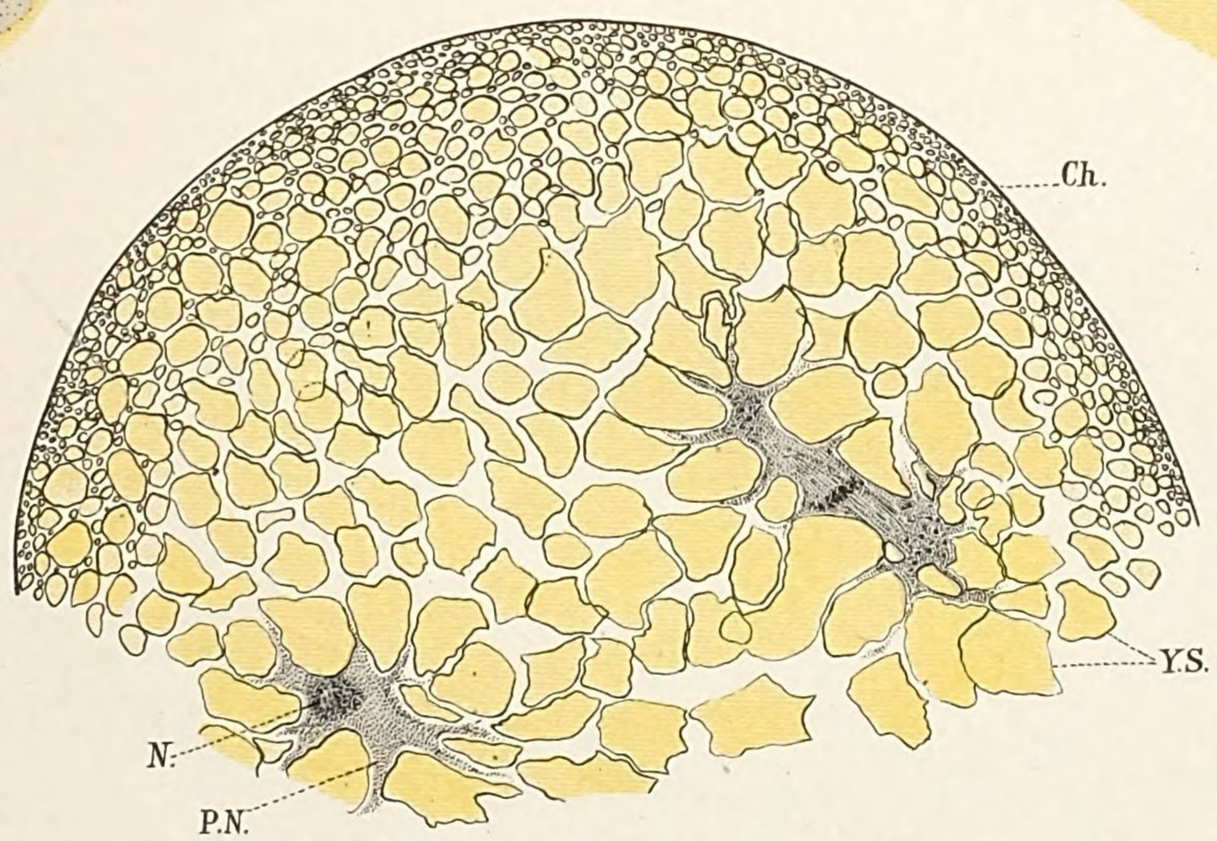


Fig.28.

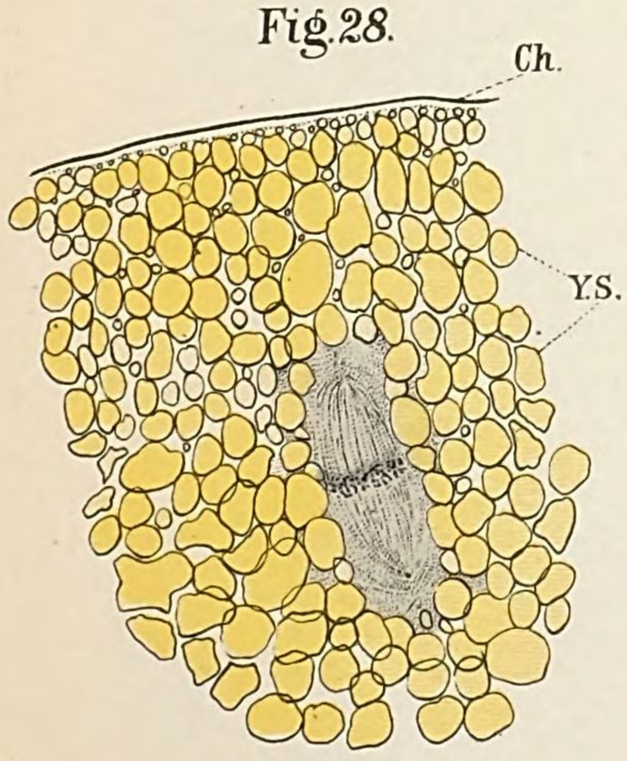


Fig.29.

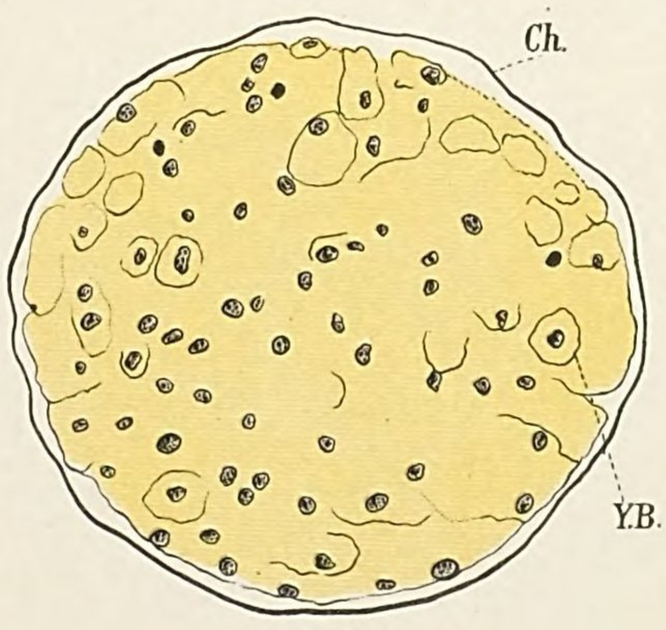
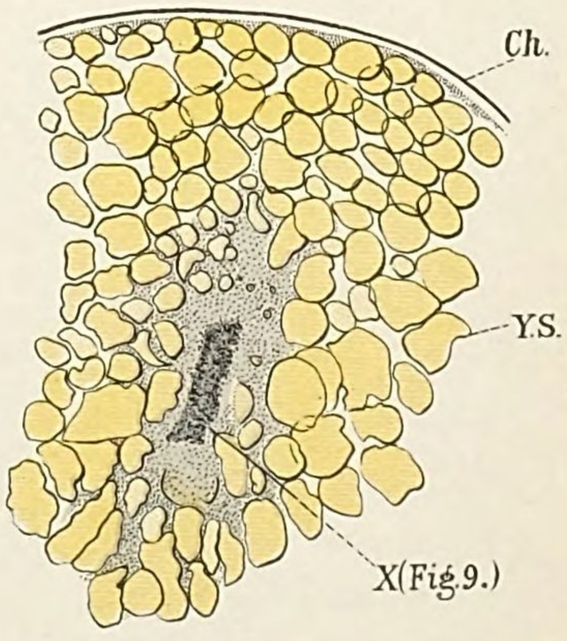


Fig.30.



F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS AND PONTONIA.

Plate XXIX.

Fig. 31. Part of section of egg of Bahaman variety of *Alpheus heterochelis*, showing two yolk pyramids. Same stage as Fig. 15. Sixty-four cells present. ×277.

Fig. 32. Part of transverse section of egg-nauplius of *A. saulcyi*, showing the fold of one of the antennæ and the mesoblastic cells and degenerative products contained within it. ×610.

Fig. 33. Wandering cells in yolk above the same embryo, showing protoplasmic union. ×610.

Fig. 34. Part of section of egg of the Bahaman *heterochelis* in egg-nauplius stage, showing wandering cells, which have left the yolk and have attached themselves to the superficial ectoblast. The nuclei are flattened against the surface, but are clearly distinguished from the epiblast. ×610.

Fig. 35. Part of transverse section of older embryo, showing blood cells and wandering mesoblast cell (*Mes.*). Eye-pigment beginning to form. ×610.

Fig. 36. Part of longitudinal section of embryo shown in Fig. 153, to show the degenerative products of the dorsal plate. ×610.

REFERENCE LETTERS.

App., appendage.
A. Y. S., altered yolk.
B. C., blood corpuscle.
Ch., egg membranes.
C. P., united pseudopodia of two wandering cells.
Ect., ectoblast.
Ep., spindle-shaped nuclei of surface epiblast.
Mes., *Mes.*[1], mesoblast.
Mu., muscle cells.
Pn., cell protoplasm.
Pl., coagulated blood.
s, *s*[1], degenerative cell products.
Sep., inner wall of yolk pyramid.
S. W., outer wall of yolk pyramid.
Y. C., wandering cells.
Y. S., yolk sphere.
Vac., vacuole.

Fig. 31.

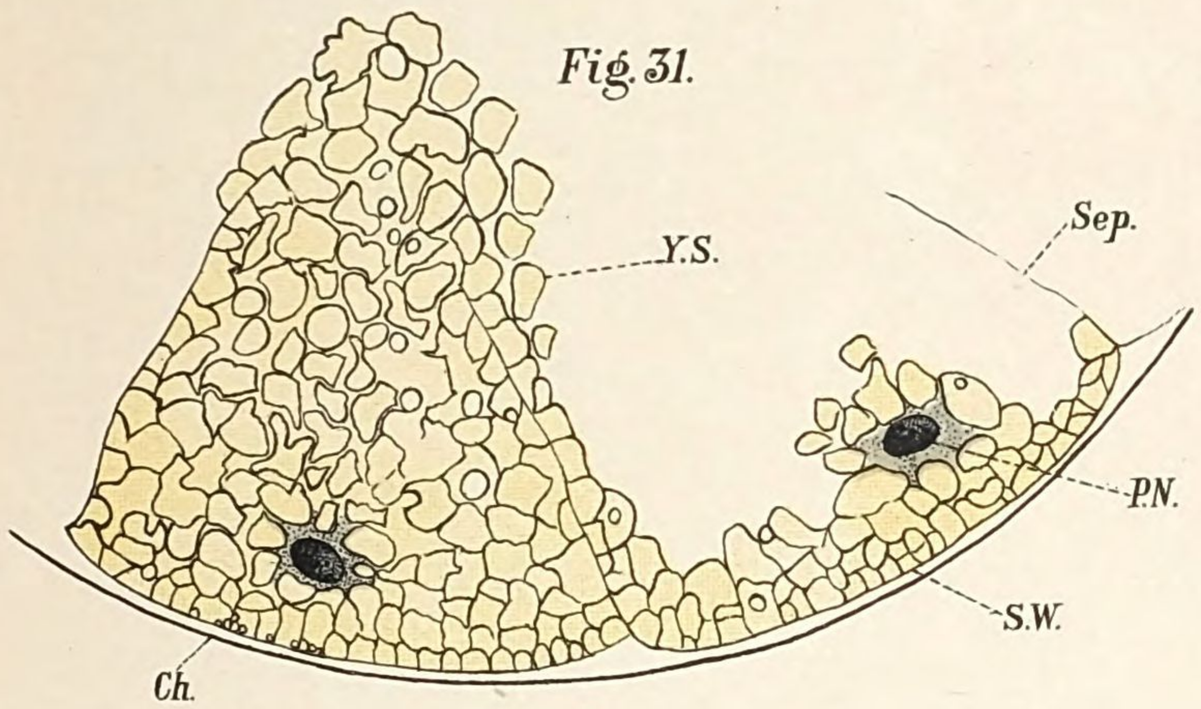


Fig. 33.

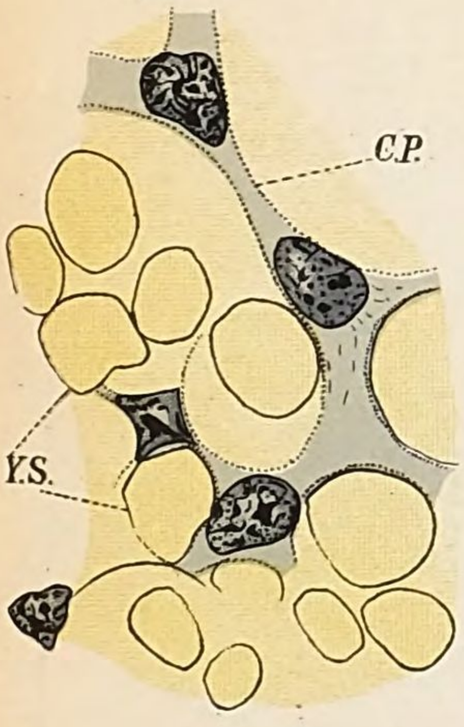


Fig. 32.

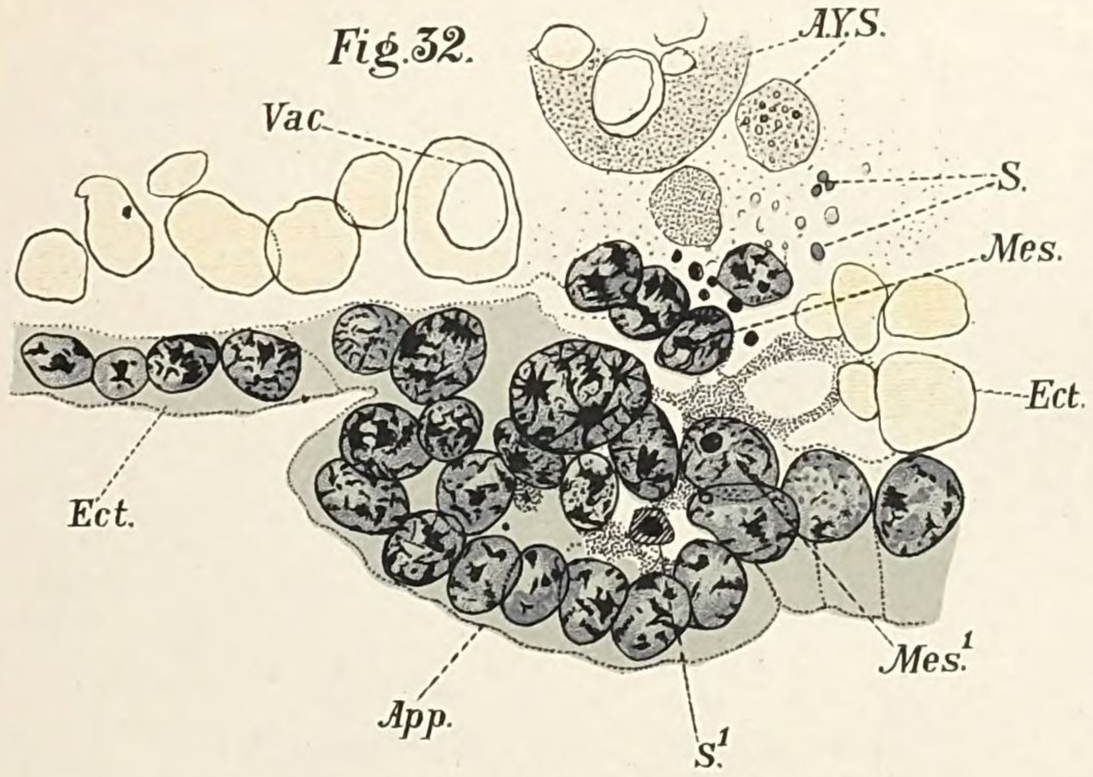


Fig. 34.

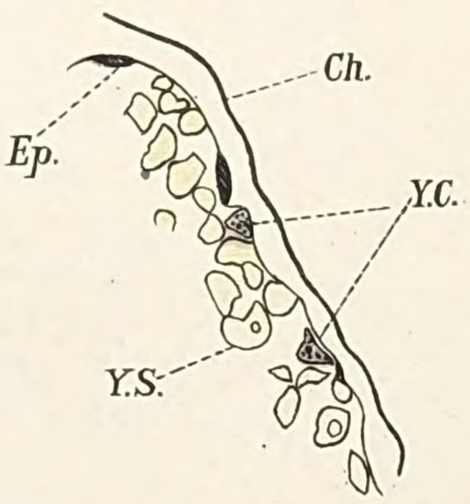


Fig. 35.

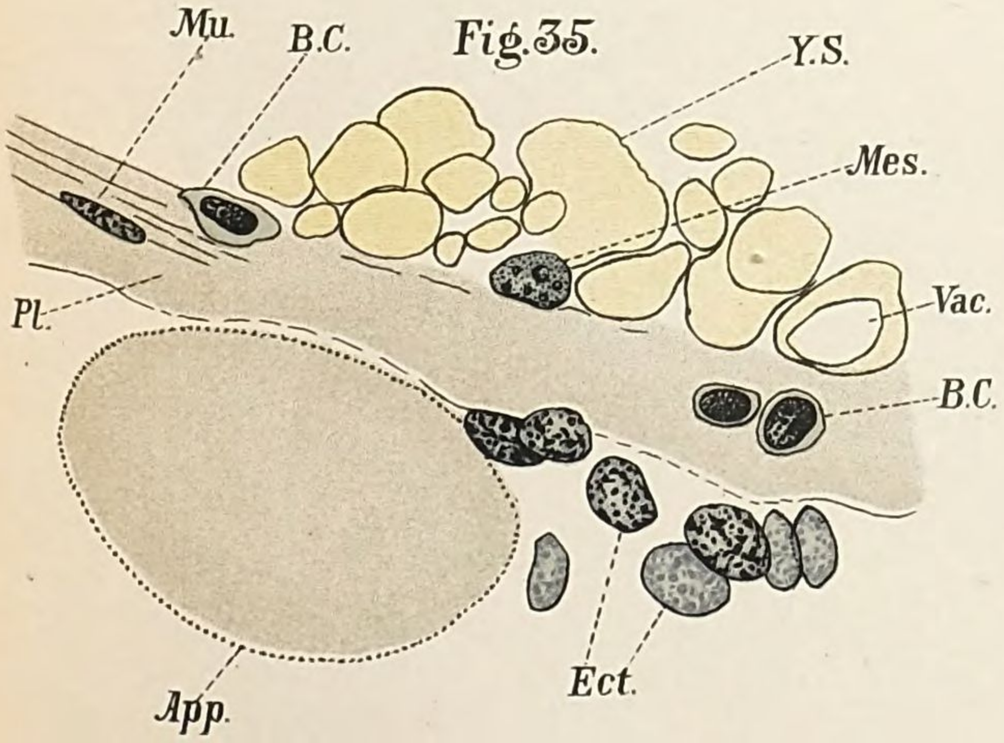
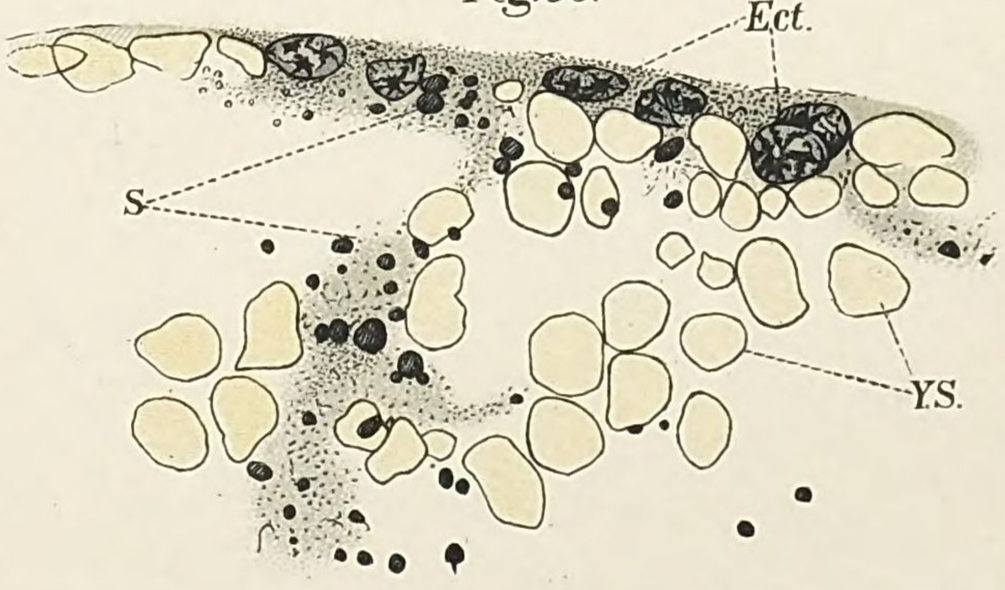


Fig. 36.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

Plate XXX.

Fig. 37. Part of section of egg before invagination stage, showing primary yolk cells. All the figures on this plate, excepting Fig. 46, refer to the Bahaman form of *Alpheus heterochelis*. ×277.

Fig. 38–44. Consecutive sections of the same egg, showing the progress of the primary yolk cells in their migration from the blastoderm to the central parts of the egg. ×70.

Fig. 45. Section through the same egg, showing semidiagrammatically the structure of the yolk. ×70.

Fig. 46. Section through the egg of *A. saulcyi* at a slightly later stage, but before invagination. The blastodermic cells lie at the surface, the primary yolk cells toward the center of the egg. Traces of the primary yolk cleavage are still seen at the surface, and a secondary cleavage has occurred below the surface. ×70.

Fig. 47. Surface view of the side of egg, corresponding to the germinal area in nearly the same stage. ×70.

Fig. 48. Tangential section, showing blastodermic cells of same egg. ×277.

REFERENCE LETTERS.

a, a^{1-7}, cells migrating from blastoderm into the yolk.
Bd. C., blastodermic cell.
Ch., eggshell.
G. D., embryonic area.
Sep., yolk cleavage plane.
Y. B., yolk ball.

Fig.37.

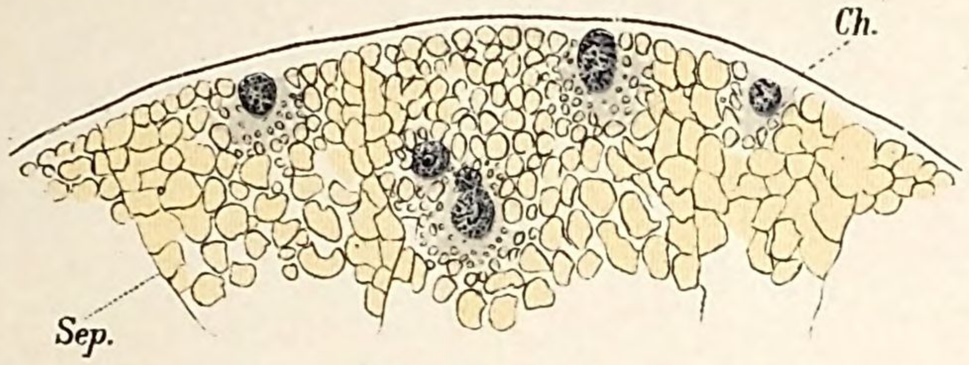


Fig.38.

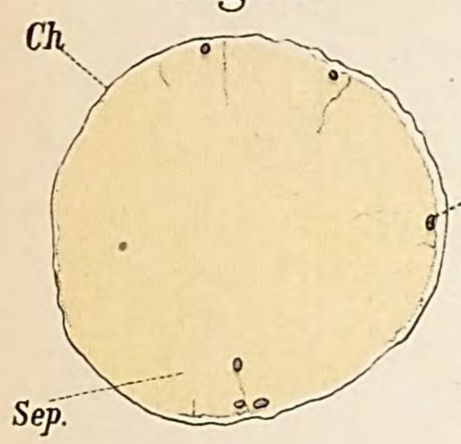


Fig.39.

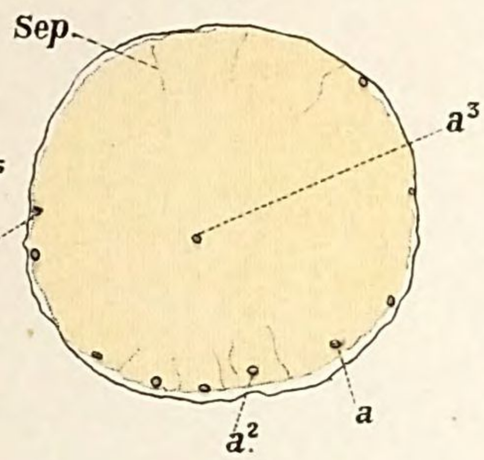


Fig.40.

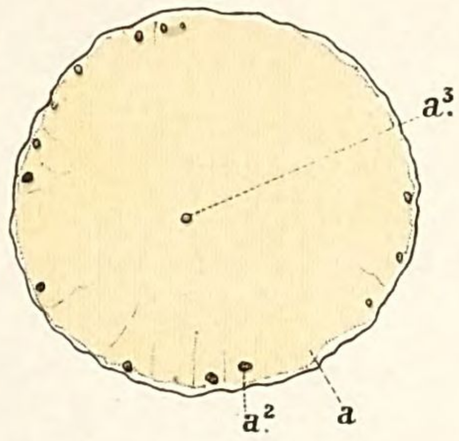


Fig.41.

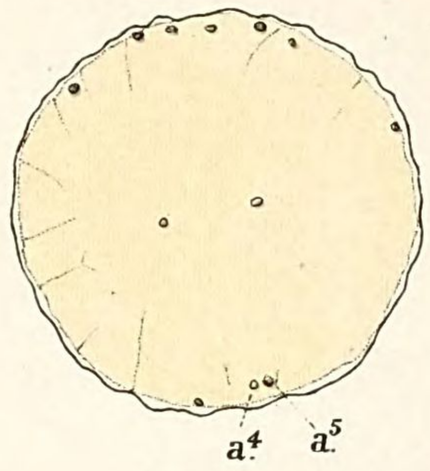


Fig.42.

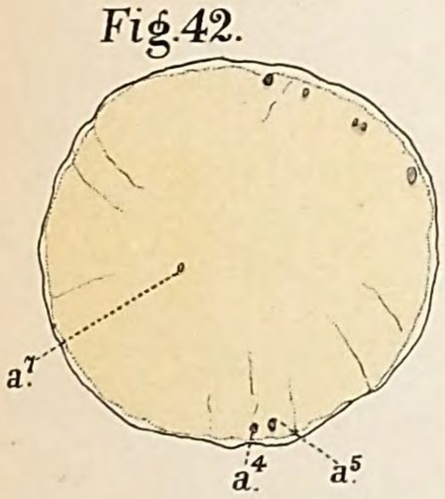


Fig.43.

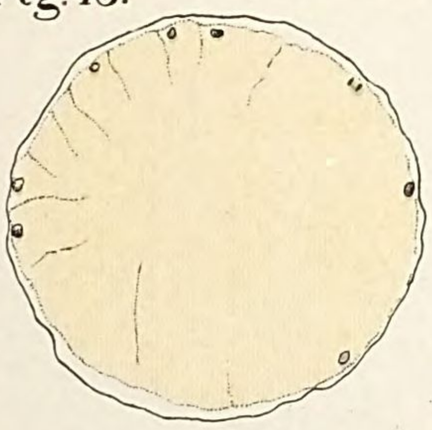


Fig.44.

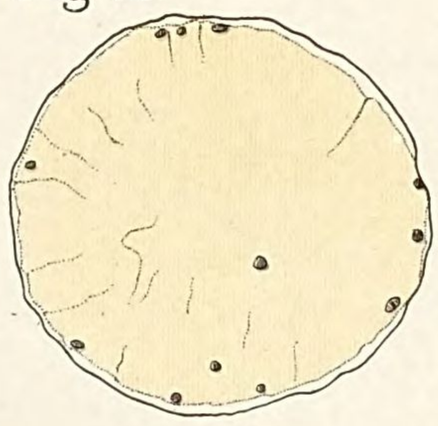


Fig.45.

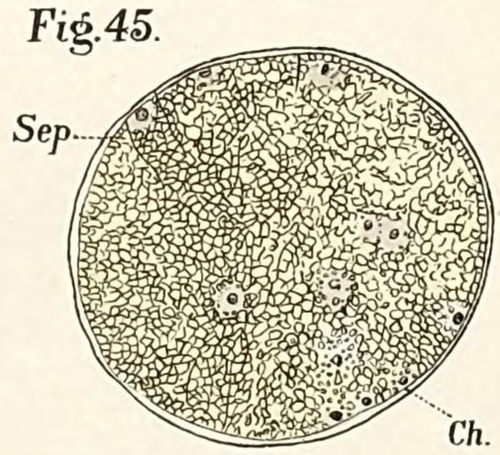


Fig.46.

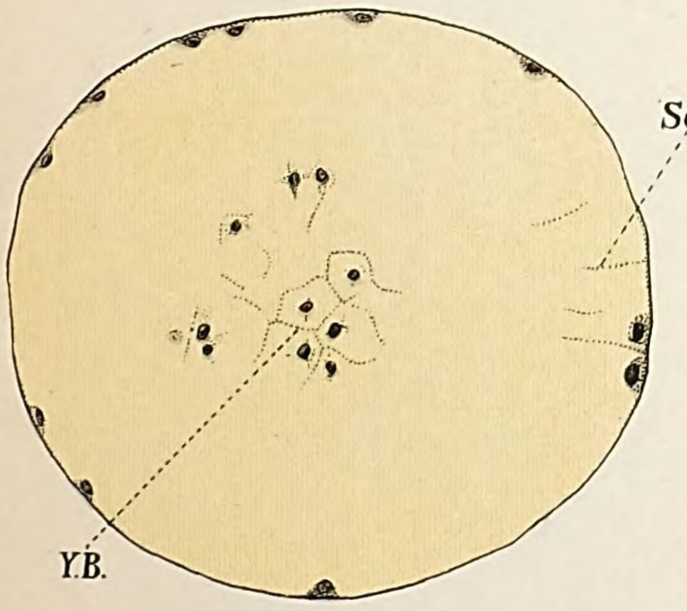


Fig.47.

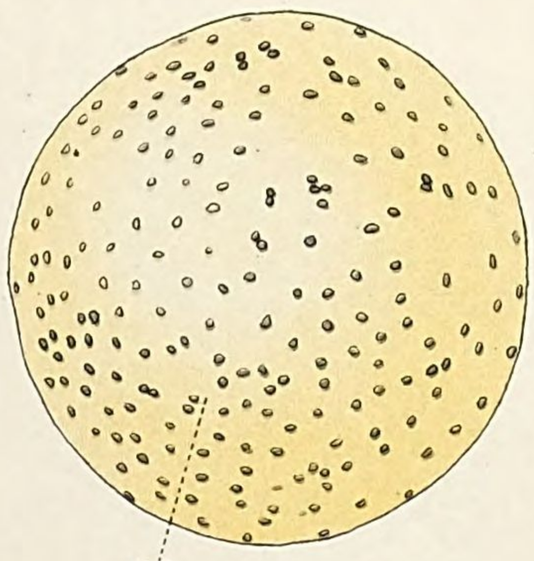
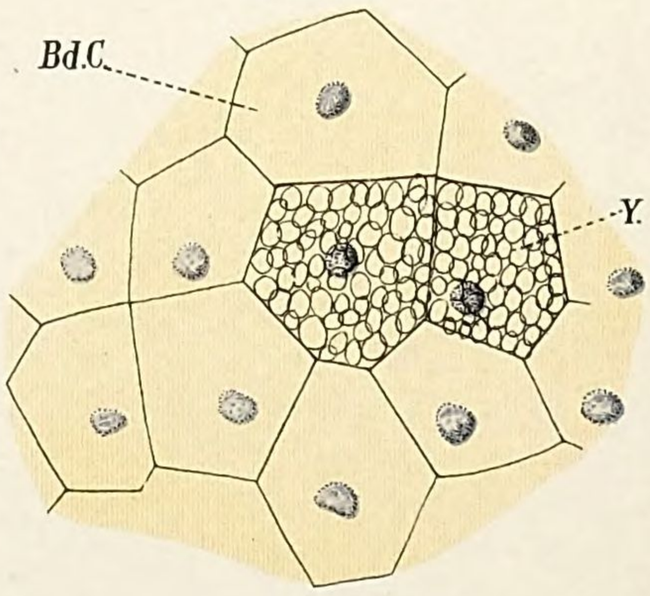


Fig.48.



F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS

PLATE XXXI.

FIGS. 49–55. Serial transverse sections through the embryo in the invagination stage. In the most anterior section the germinal area (*G. D.*) is traversed, and in Fig. 53 the shallow depression in the middle of the invaginate area is cut through. In Fig. 54 (*G. D.*) we see the forward extension of the invaginate cells and the first trace of the thoracic-abdominal plate. The distinction between the primary yolk cells (Figs. 49, 52, 53–55) and the invaginate wandering cells (*b*, $b^{2\text{-}5}$, Figs. 52–54) and their product, which now begin their migrations, is very plainly shown. In Fig. 50, which cuts the shallow pit at the surface of the invaginate area, we see the amœboid cells with large granular nuclei making their way from the bottom of the pit into the depths of the yolk. Figs. 49, 52–55, ×115. Figs. 50, 51, ×291.

REFERENCE LETTERS.

b, b^2-b^5, in-wandering cells derived from the invaginate cells and their products.
Ch., egg capsule or shell.
Ep., ectoblast.
G. D., embryonic area.
I. C., invaginate cell.
Ig., pit formed by the invagination.
Y. B., yolk ball.
P. Y. C., primary yolk cell.
Y. S., yolk sphere.

Fig. 49.

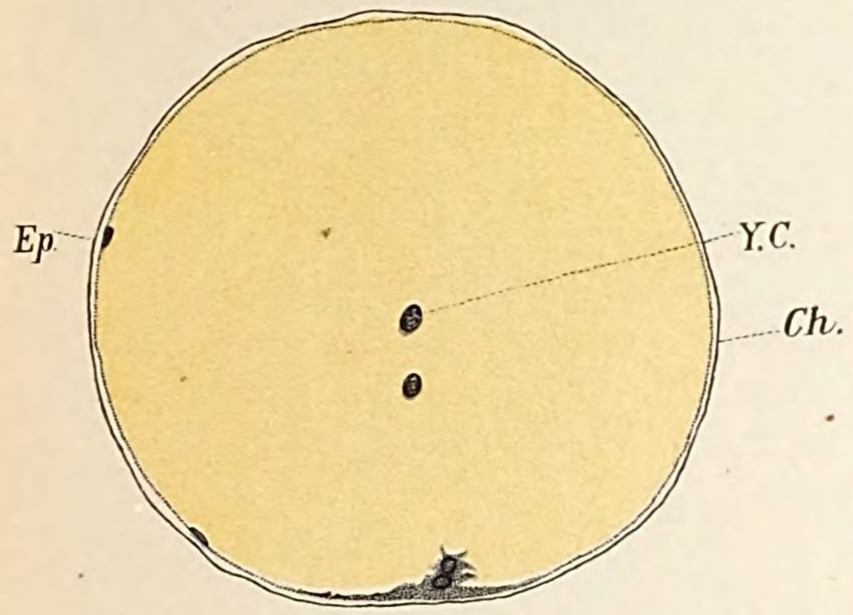


Fig. 50.

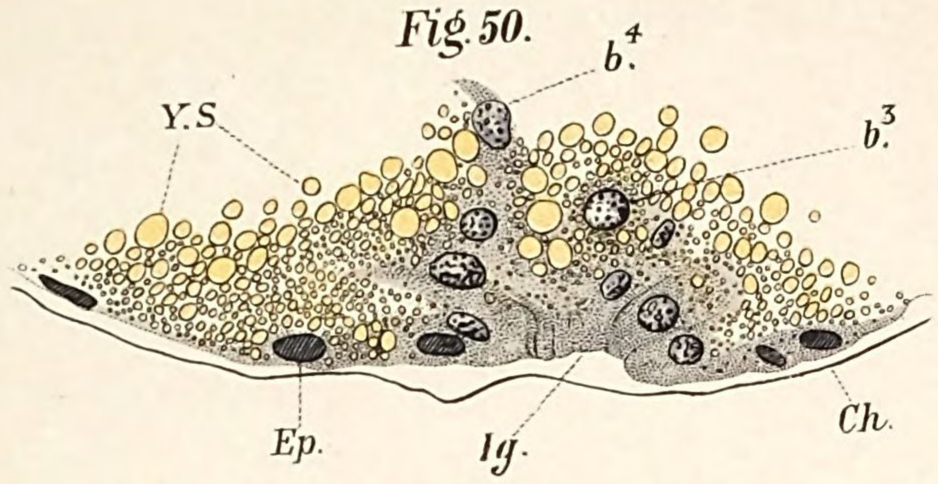


Fig. 51.

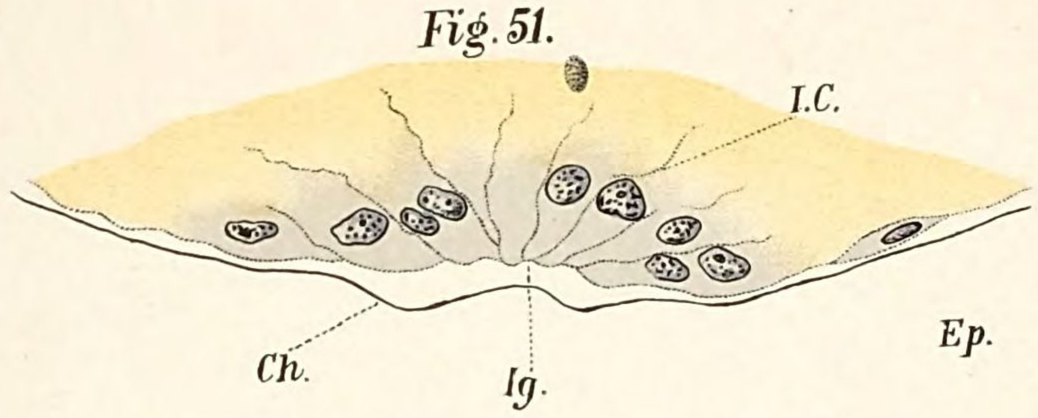


Fig. 52.

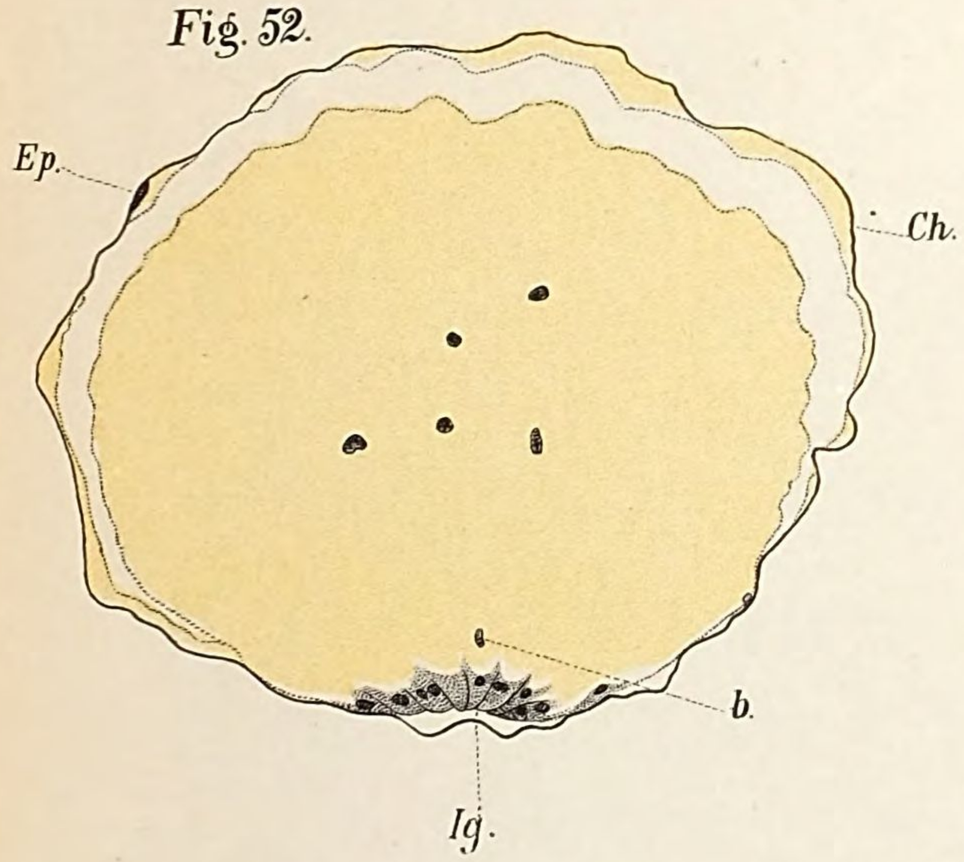


Fig. 54.

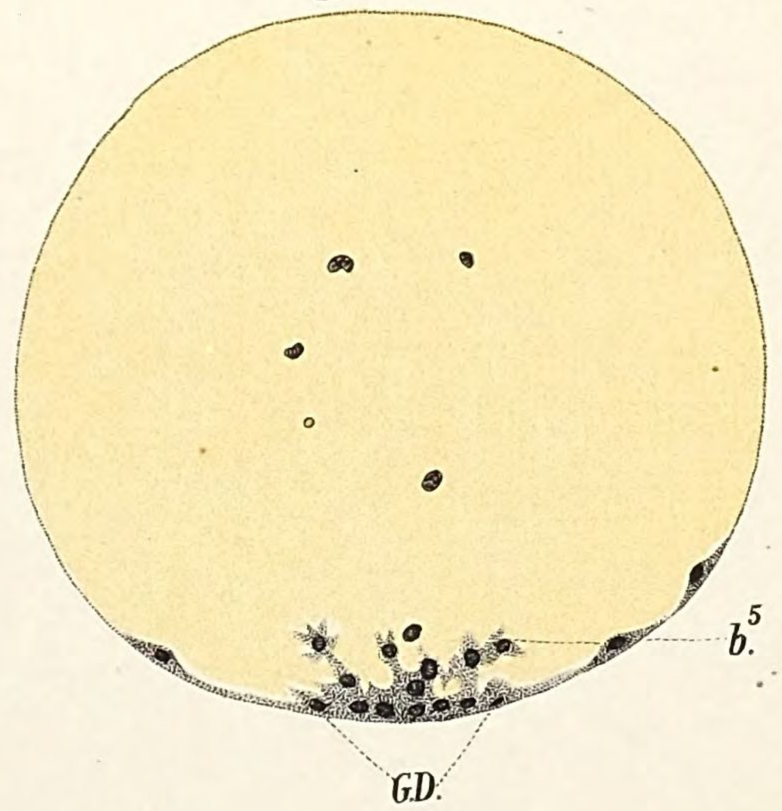


Fig. 53.

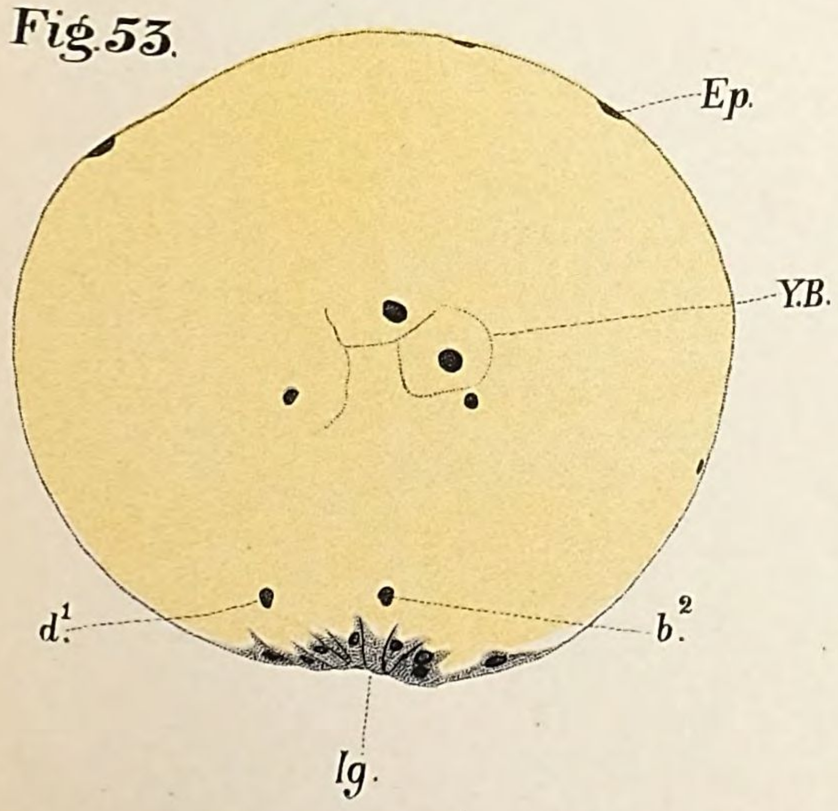
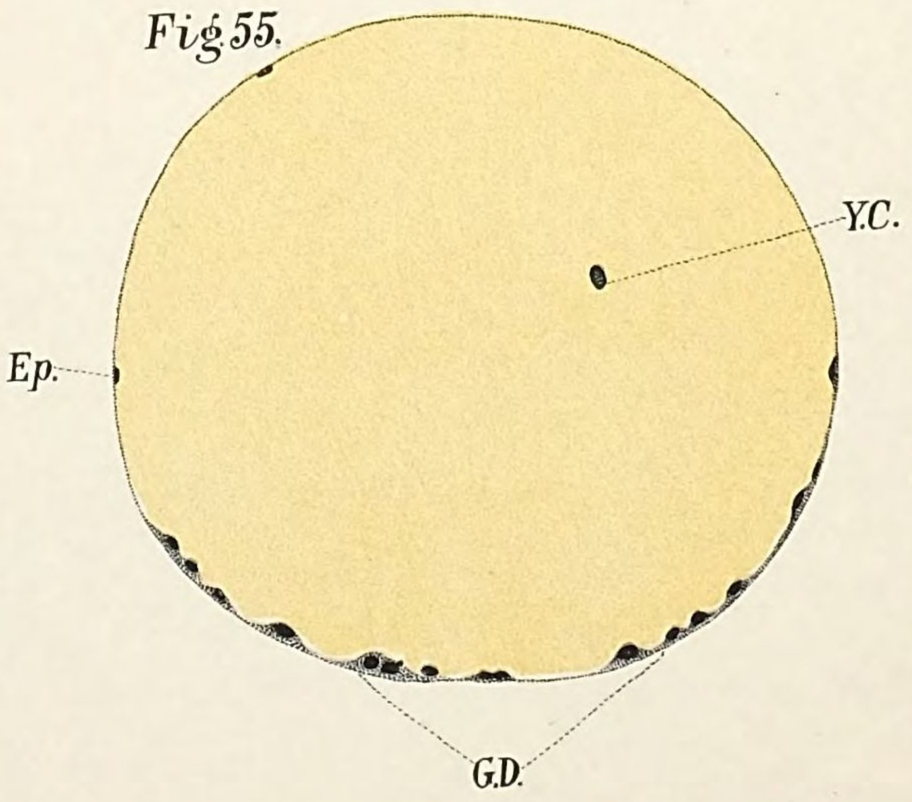


Fig. 55.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

PLATE XXXII.

FIGS. 56, 59, 60. Longitudinal serial sections through the entire embryo in the stage shown in Fig. 58. Fig. 59 is median. The primary yolk cells (*P. Y. C.*, Fig. 60) can still be distinguished from the wandering cells derived from the invagination (*S. Y. C.*, Fig. 60). In Fig. 59 a primary yolk cell (*P. Y. C.*[1]) is in the metakinetic stage of division. Traces of the primary segmentation of the yolk are still present, and the secondary yolk segmentation is very marked in the neighborhood of the wandering cells. Where the shell (*Ch.*) is not removed it is seen to be considerably distended and to have epiblastic cells sticking to it, showing the close adherence which normally exists between the egg membranes and the egg. ×115.

FIG. 57. Section through egg, cutting germinal disk just before invagination. Twenty and one-half hours older than yolk-pyramid stage seen in Fig. 15. ×73.

FIG. 58. Surface view of embryo after the appearance of the thoracic-abdominal plate and the optic disks. The shallow depression which marked the invaginate area has disappeared. Its approximate position is indicated by *Ig.* Compare *Ig.*, Fig. 59. ×291.

REFERENCE LETTERS.

Ab. P., ventral plate.
Ch., eggshell.
Ep., *Ep.*[1], ectoderm.
G. D., germinal disk.
Ig., pit of invagination.
L. Cd., lateral ventral bands.
O. D., optic disk.
P. M., wandering cells, seen below surface, coming off from ventral plate.
P. Y. C., *P. Y. C.*[1], primary yolk cells.
Sep., yolk cleavage plane.
S. Y. C., *S. Y. C.*[1], wandering cells derived from the invaginate cells and their products.
T. Cd., cell area uniting optic disks.
Y. B., yolk ball.
Y. C., primary yolk cell.

Fig.56.

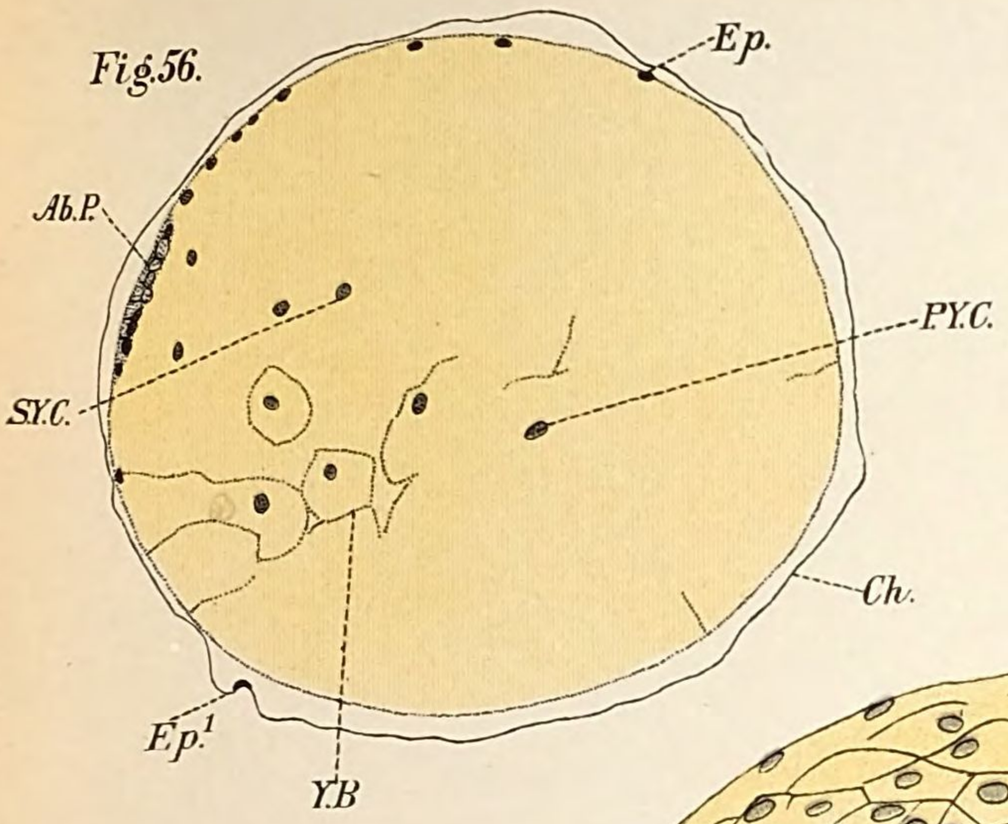


Fig.57.

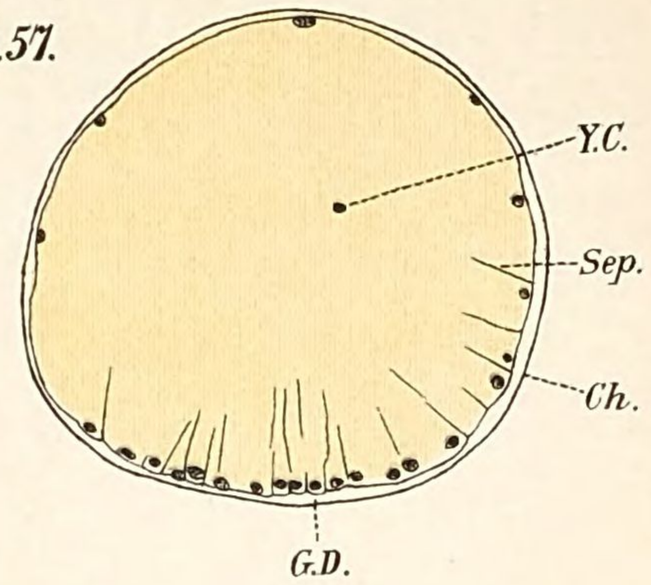


Fig.58.

Fig. 59.

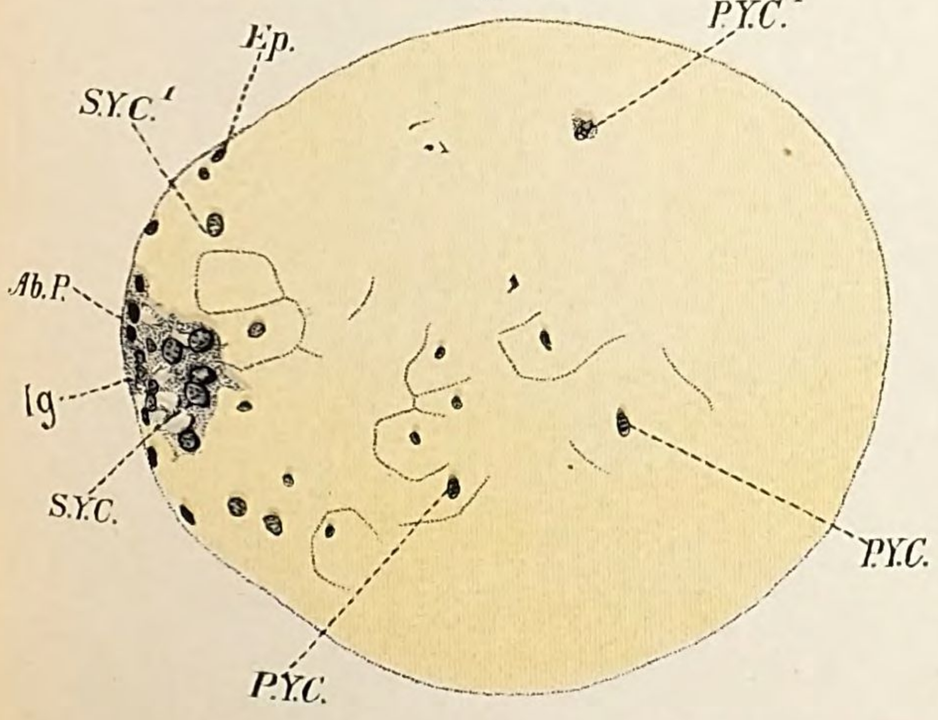
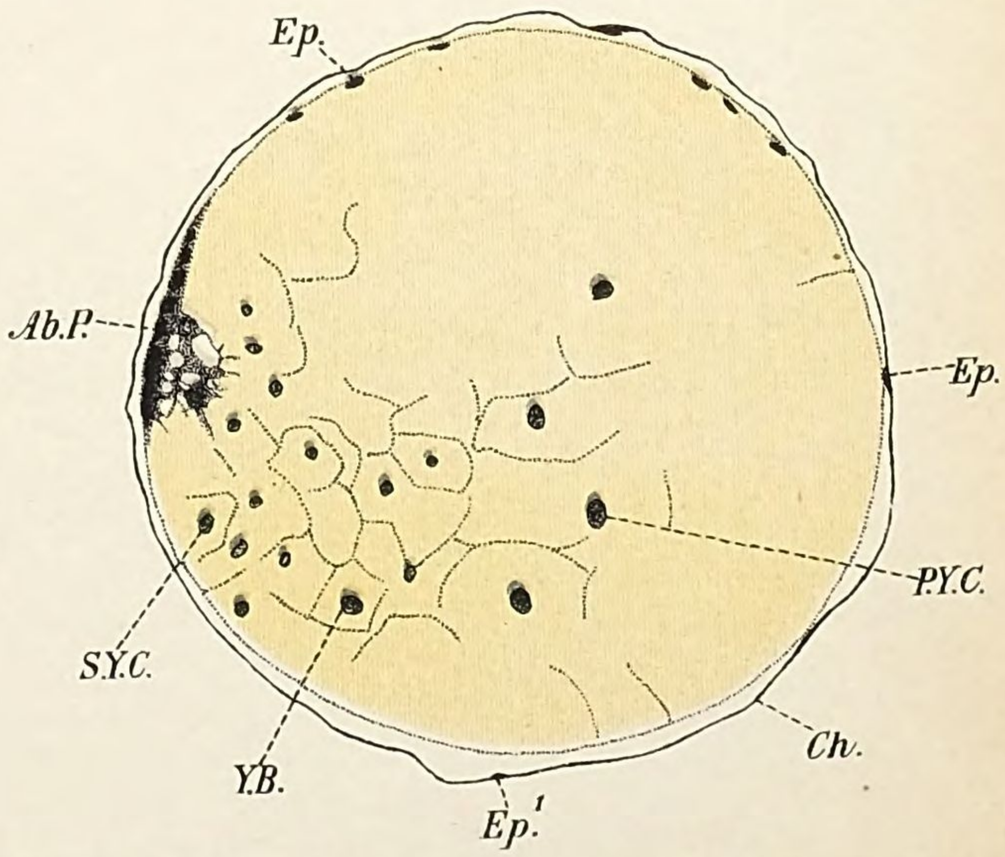


Fig. 60.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS

Plate XXXIII.

Figs. 61, 62, 68, 69. Transverse sections of embryo in stage shown in Fig. 58, Pl. xxxii. Fig. 61 cuts the thoracic-abdominal plate, and Figs. 68 and 69 involve the optic disks. Primary yolk cells (*P. Y. C.*, Fig. 69) are still plainly distinguishable. ×115.

Fig. 63. Portion of median longitudinal section of the same stage. The larger and clearer nuclei in the invaginate area represent the mother cells of both mesoderm and endoderm. The yolk ball or secondary yolk segment is characteristic of this stage. ×291.

Figs. 64–67. Consecutive transverse sections of left optic disk of same stage before any thickening has occurred. The most anterior section is represented in Fig. 64. ×291.

REFERENCE LETTERS.

Ab. P., ventral plate.
Ch., eggshell.
Ep., ectoderm.
Ig., invaginate cavity.
L. Cd., lateral ventral cord.
O. D., optic disk.
P. Y. C., primary yolk cells.
Sep., yolk cleavage plane.
S. Y. C., in-wandering cells derived from ventral plate.
Y. B., yolk ball.

Fig. 61.

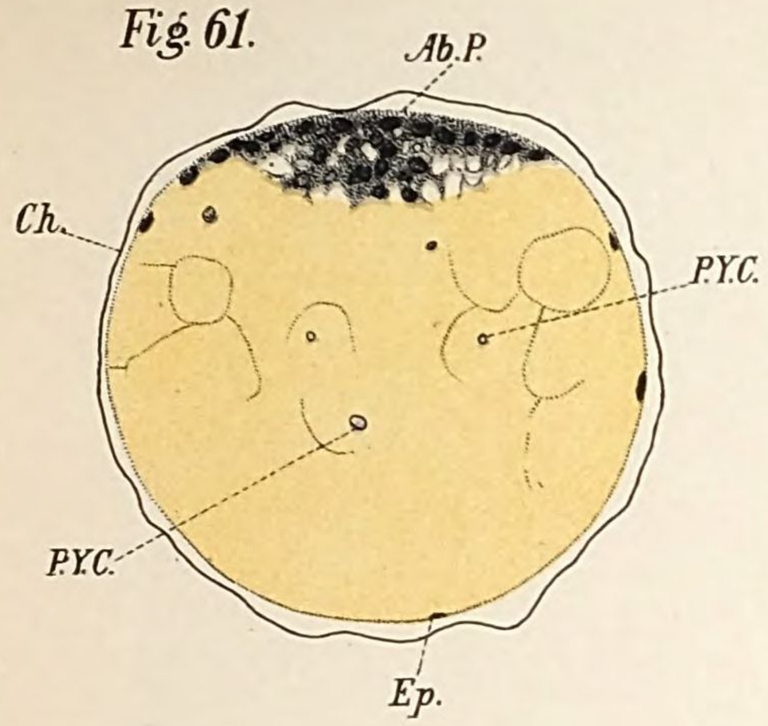


Fig. 62.

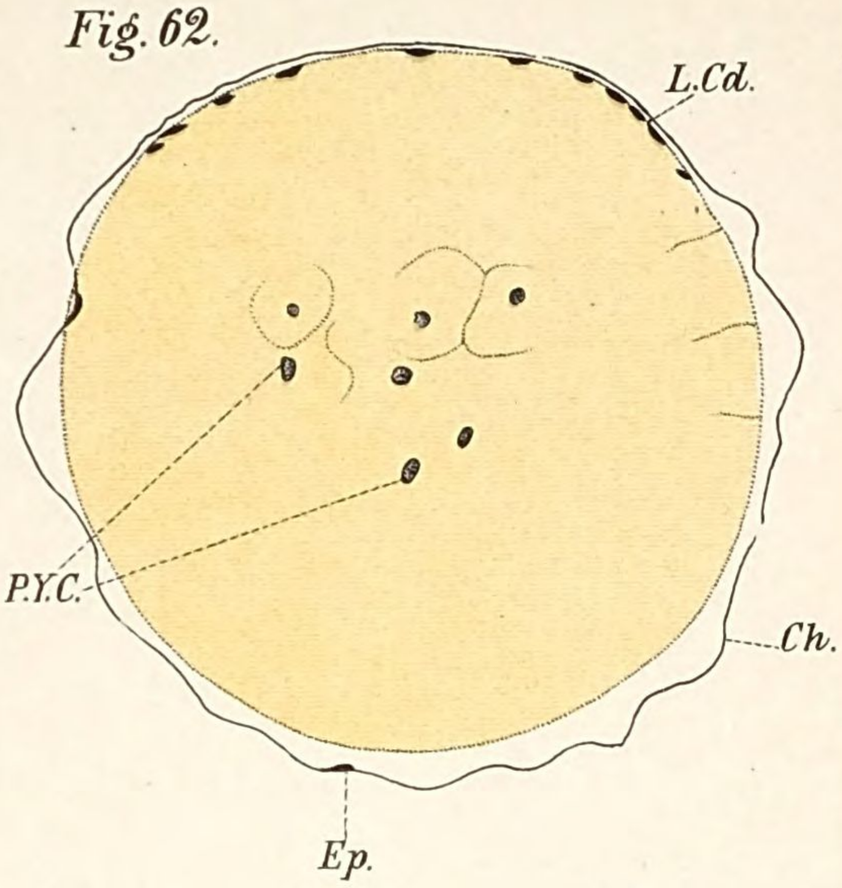


Fig. 63.

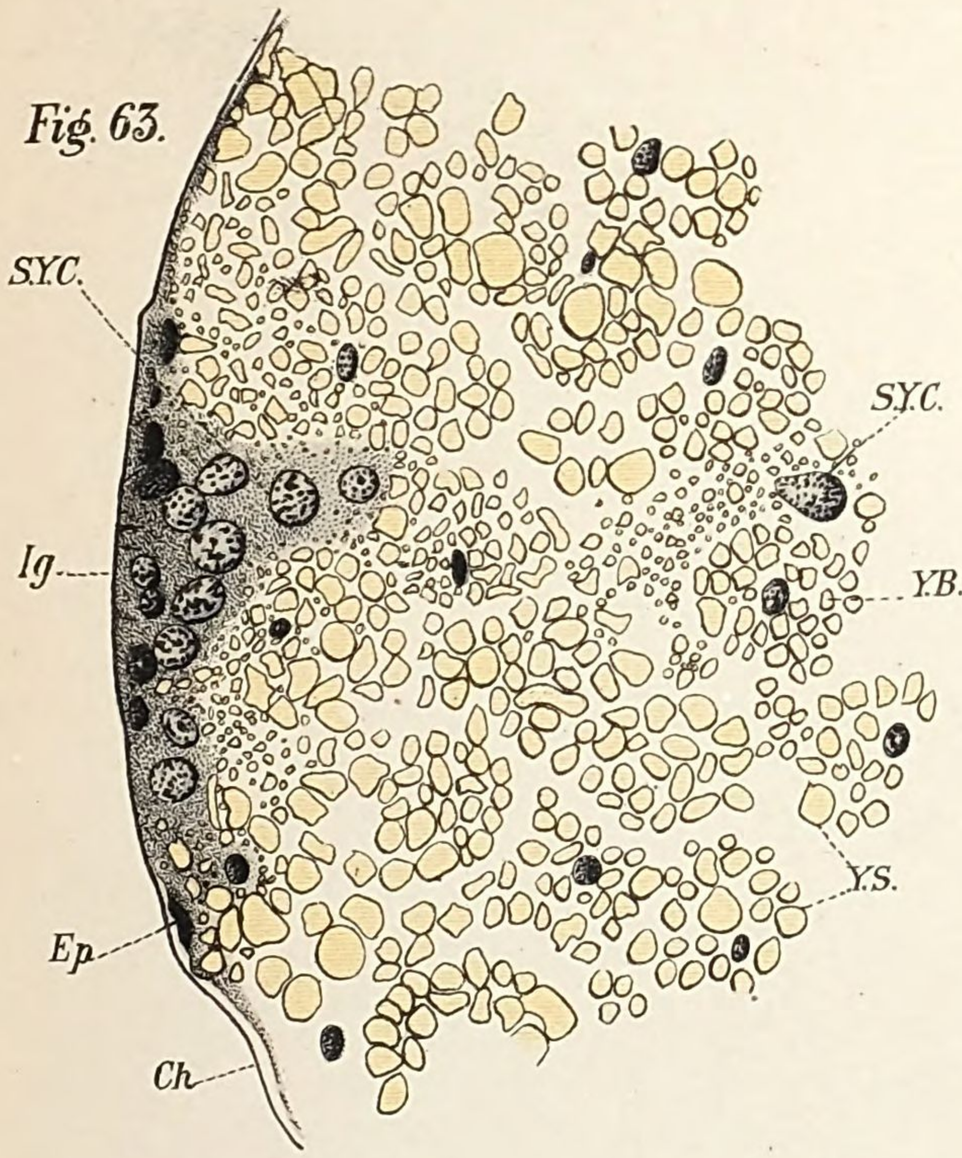


Fig. 64.

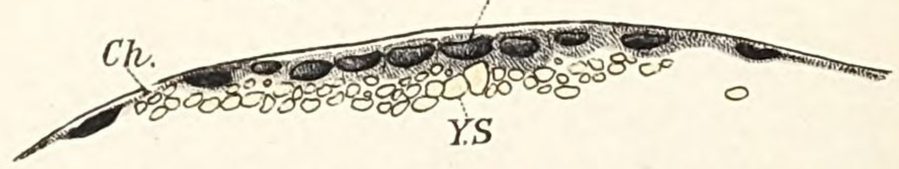


Fig. 65.

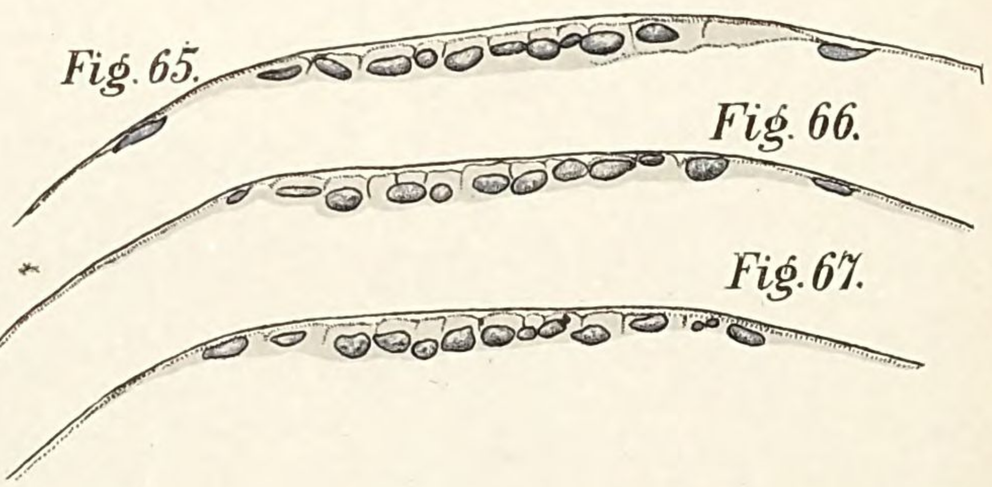


Fig. 66.

Fig. 67.

Fig. 68.

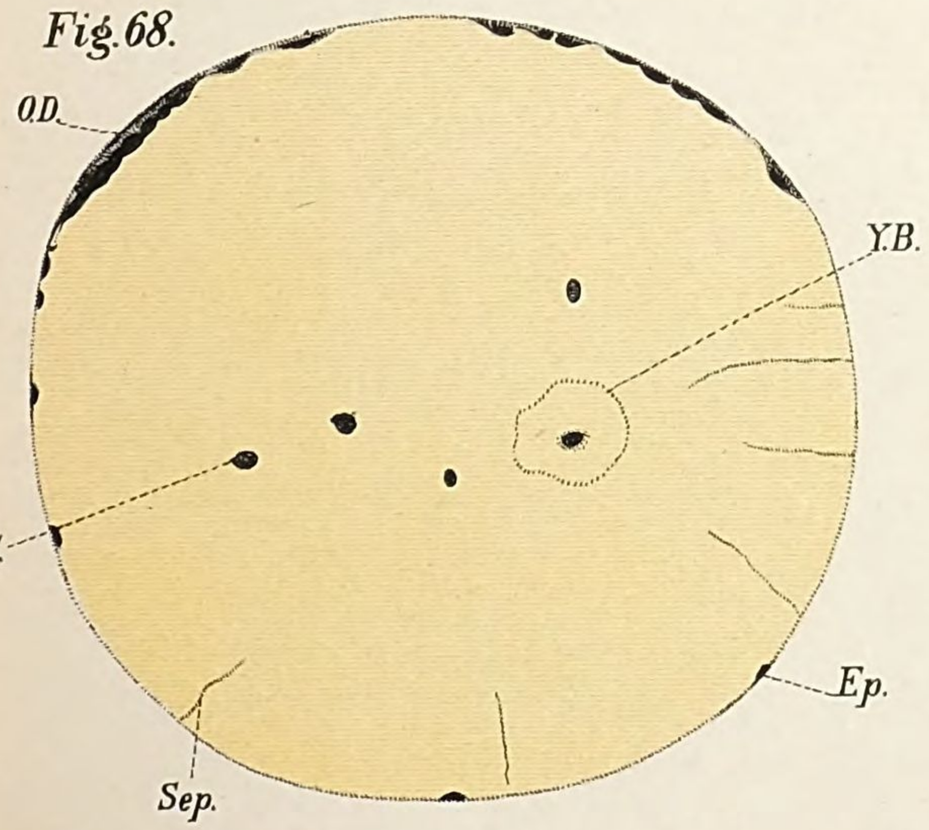
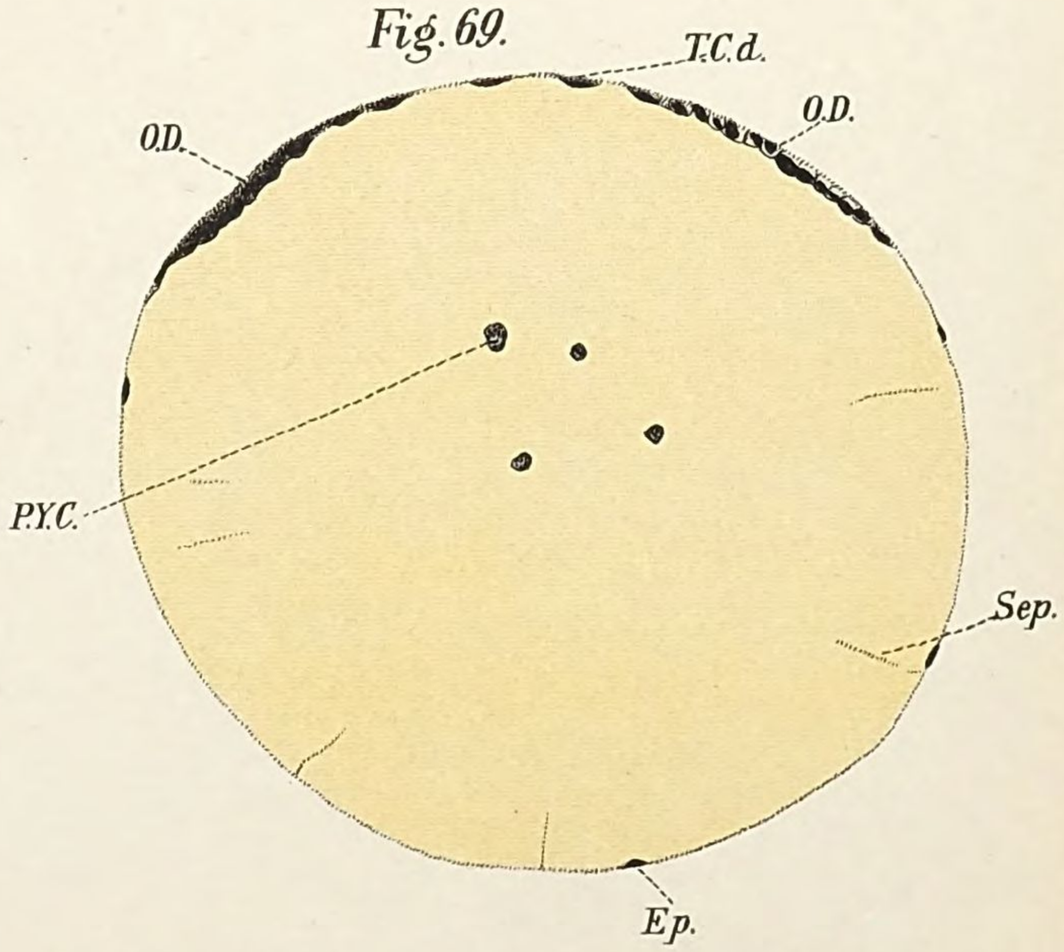


Fig. 69.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

Plate XXXIV.

(Stage IV.)

Figs. 70, 71, 73, 74. Longitudinal serial sections of the entire embryo in the stage shown in Fig. 72. In Fig. 73 the plane of section is nearly median. The primary yolk cells are now generally indistinguishable from the other wandering cells. Compare cut, Fig. 11, which shows the distribution of the wandering cells at this stage. ×115.

Fig. 72. Surface view of embryo in Stage IV. Rudiments of the mandibles and first pair of antennæ are present. An area of cell ingrowth in the optic disks (*C. M.*) is characterized by the large size of the nuclei. From them and their products the optic ganglion takes its origin. Some of the surface cells on either side of the middle line were accidentally cut away. ×291.

REFERENCE LETTERS.

A. (*I.*), proliferating center of first antenna.
Ab. P., ventral plate.
C. M., proliferating area of optic disk.
Ep., ectoderm.
L. Cd., lateral ventral cord.
Md., proliferating center of mandible.
O. D., optic disk.
T. Cd., transverse cord uniting optic disks.
Y. B., yolk ball.
Y. C., *Y. C.*^{1}, wandering cells.

Fig. 70.

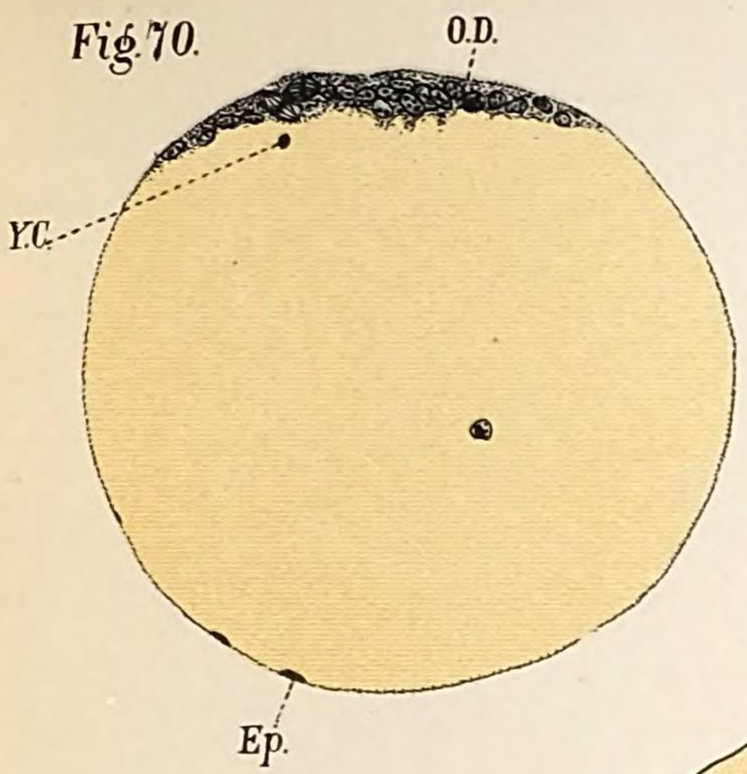


Fig. 71.

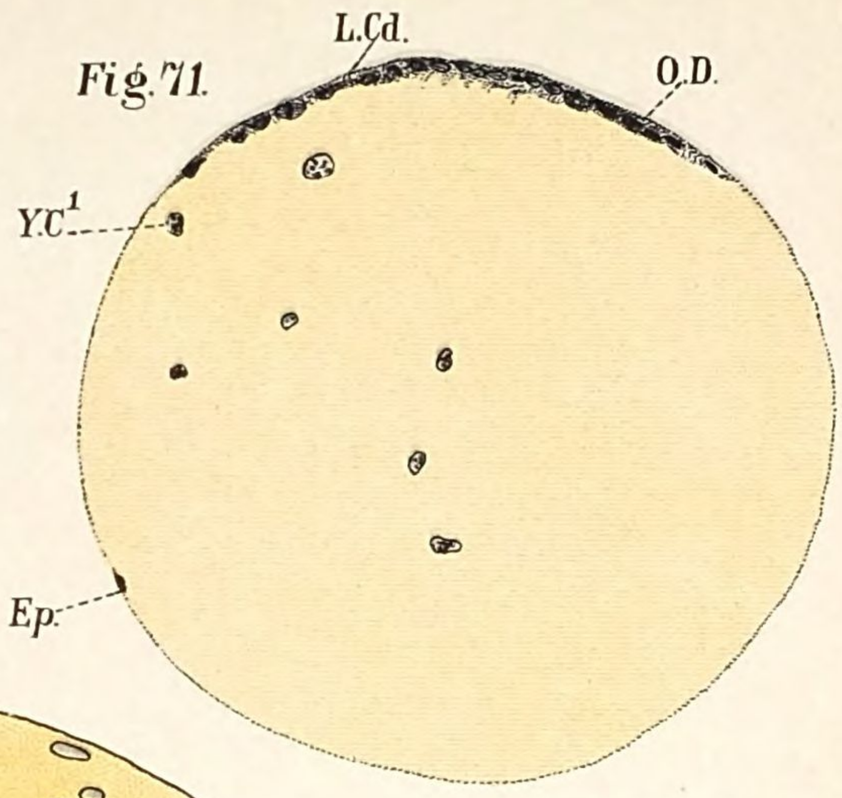


Fig. 72.

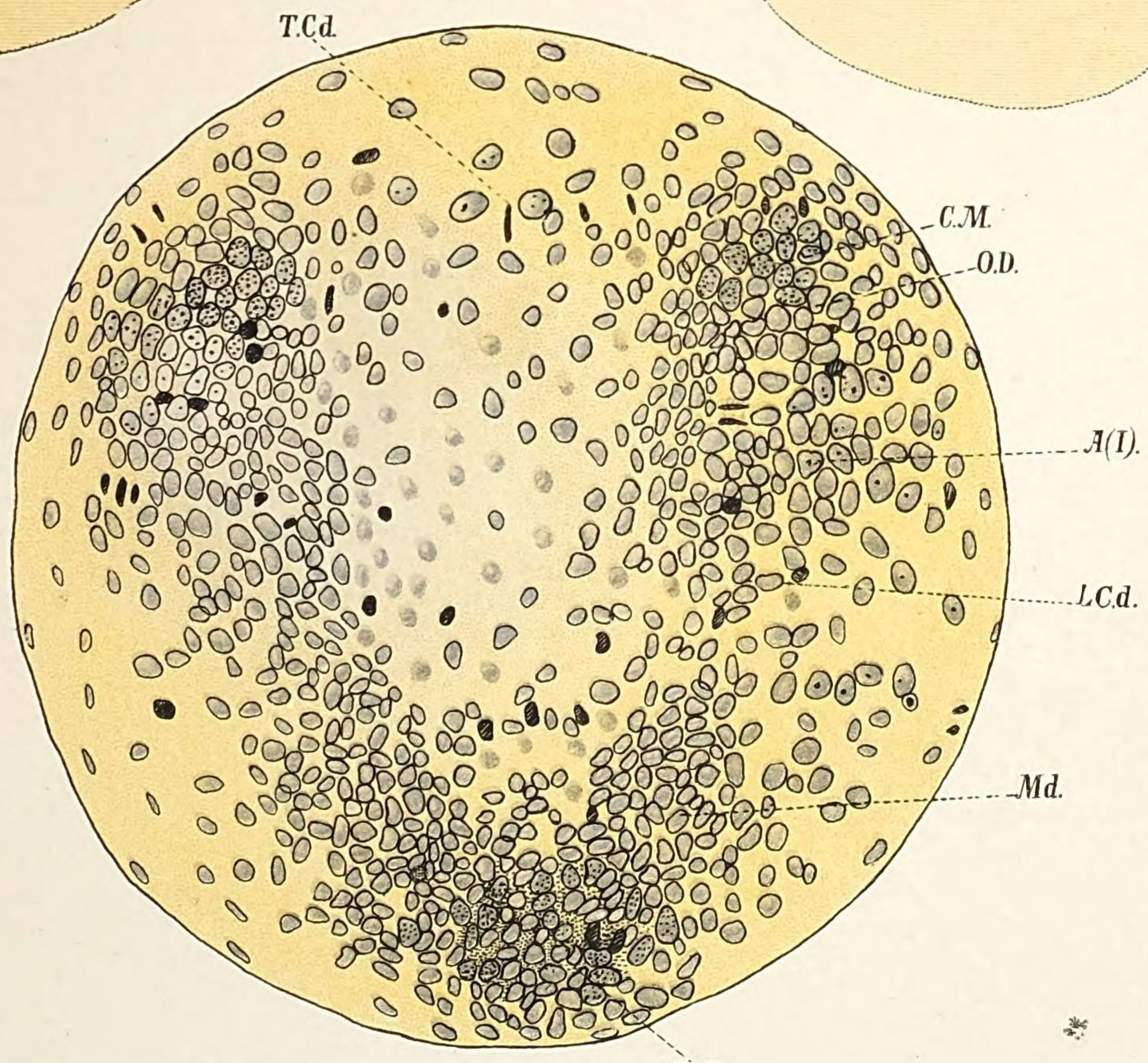


Fig. 73.

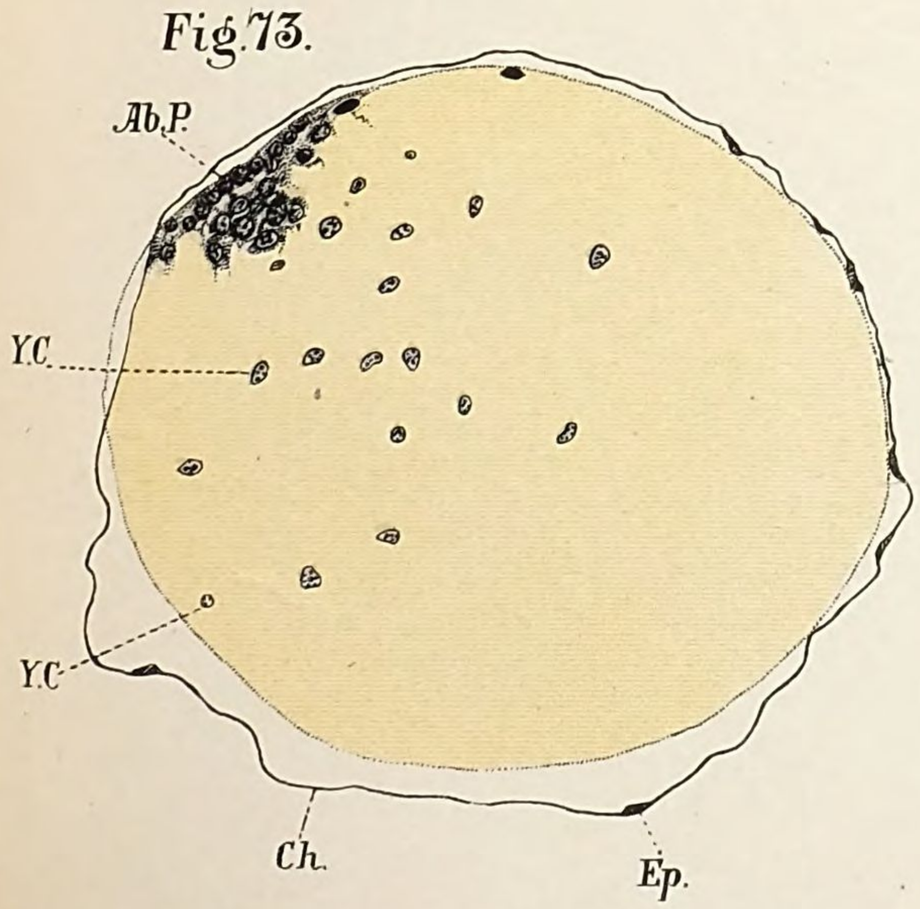
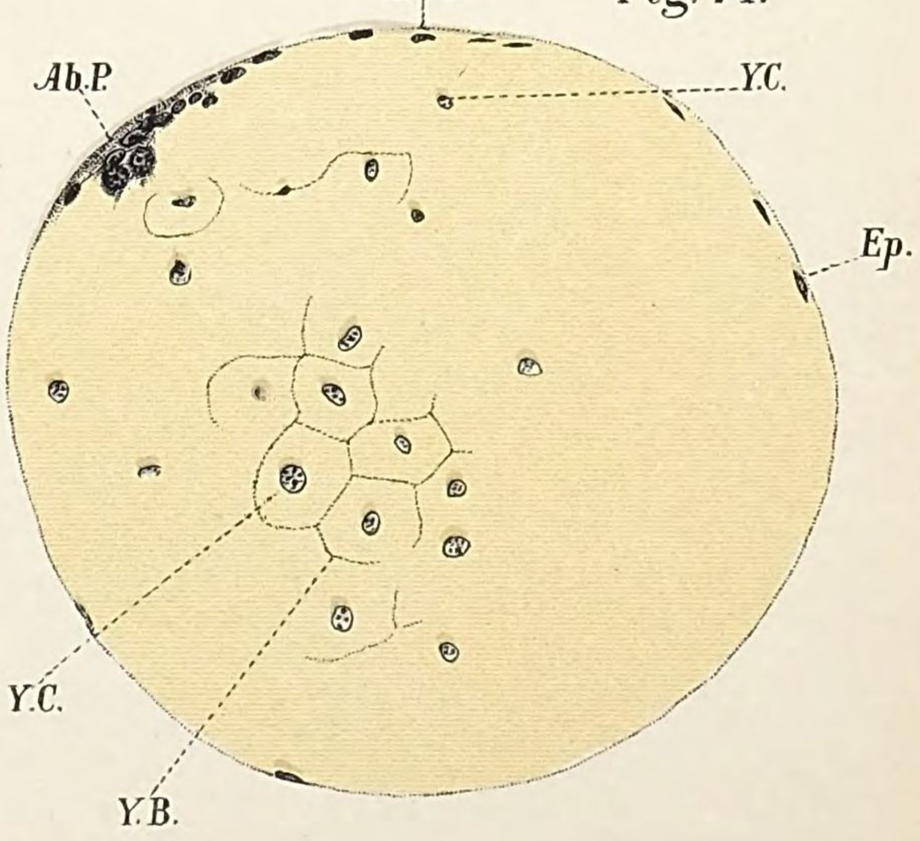


Fig. 74.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS.

PLATE XXXV.

(Stage IV.)

FIG. 75. Median longitudinal section of the entire embryo. One of the wandering cells, which is approaching the surface of the egg opposite the thoracic abdominal plate, is in the process of division. ×115.

FIGS. 76–83. Consecutive serial transverse sections through the left optic disk of same, to illustrate the earliest stages in the thickening of the disks. The most posterior section (Fig. 83) cuts the first pair of antennæ. ×291.

FIG. 84. Transverse section through the middle of optic disks. ×115.

FIG. 85. Transverse section through thoracic abdominal plate, showing the multiplication of surface cells, by which the plate is increased, and cells below the surface (*Y. C.*) which pass into the yolk. ×291.

REFERENCE LETTERS.

A. (*I*), first antenna.
Ab. P., ventral plate.
Ch., eggshell.
C. M., proliferating area of optic disk.
ec., *ec.*$^{1-3}$, ectodermic cells of ventral plate (Fig. 85). *ec.*, (Fig. 80) ectodermic cell of optic disk.
Ep., ectoderm.
O. D., *O. D*^{1}., optic disks.
Ret , protoplasmic reticulum.
T. Cd., transverse cord.
Y. B., yolk ball.
Y. C., *Y. C.*$^{1-2}$, wandering cells.
Y. S., yolk sphere.

Fig.75.

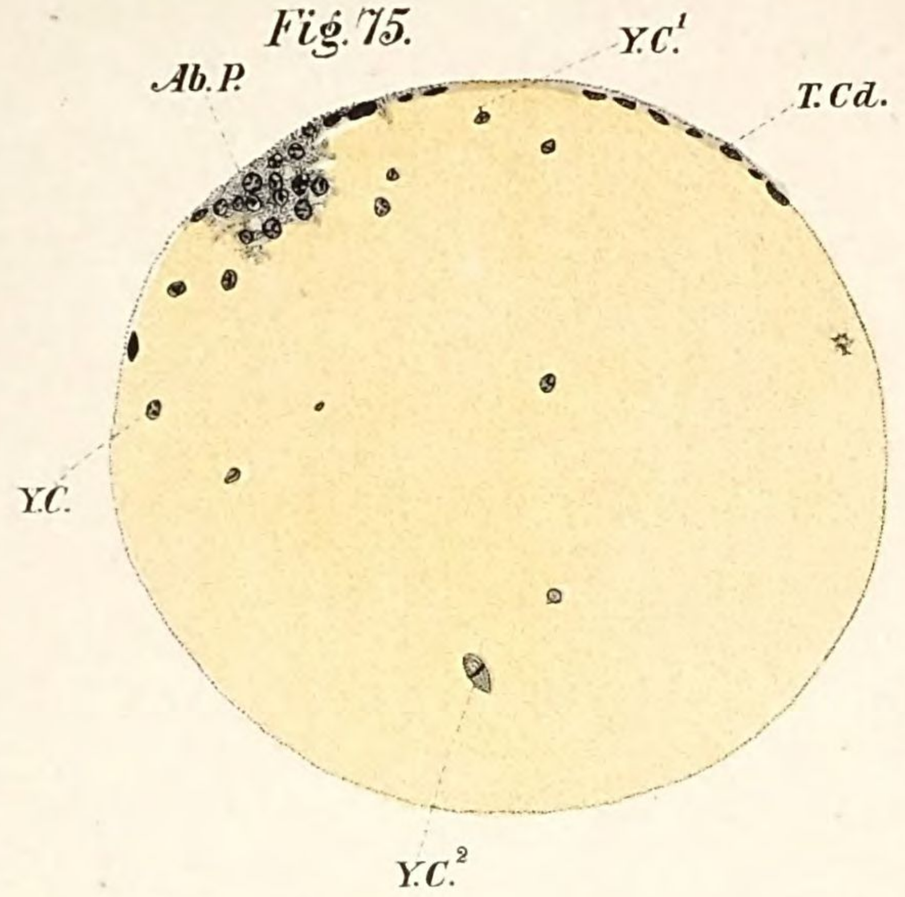


Fig.76.



Fig.77.

Fig.78.

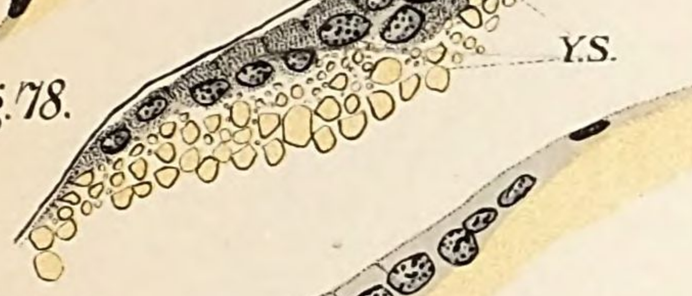


Fig.79.

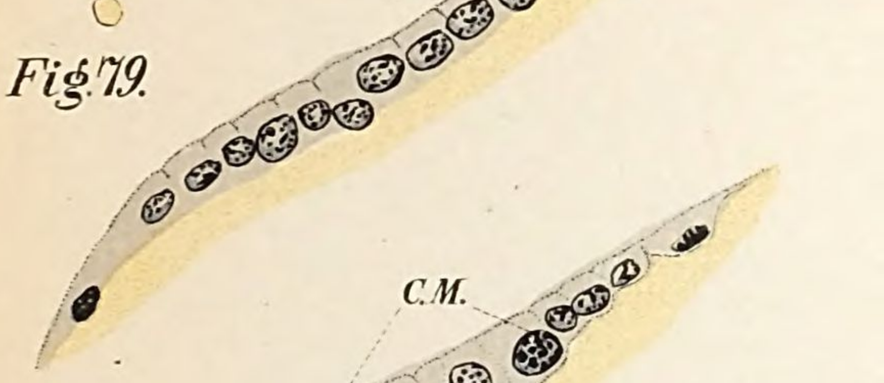


Fig.80.
(OD.¹ Fig.84)

Fig.84.

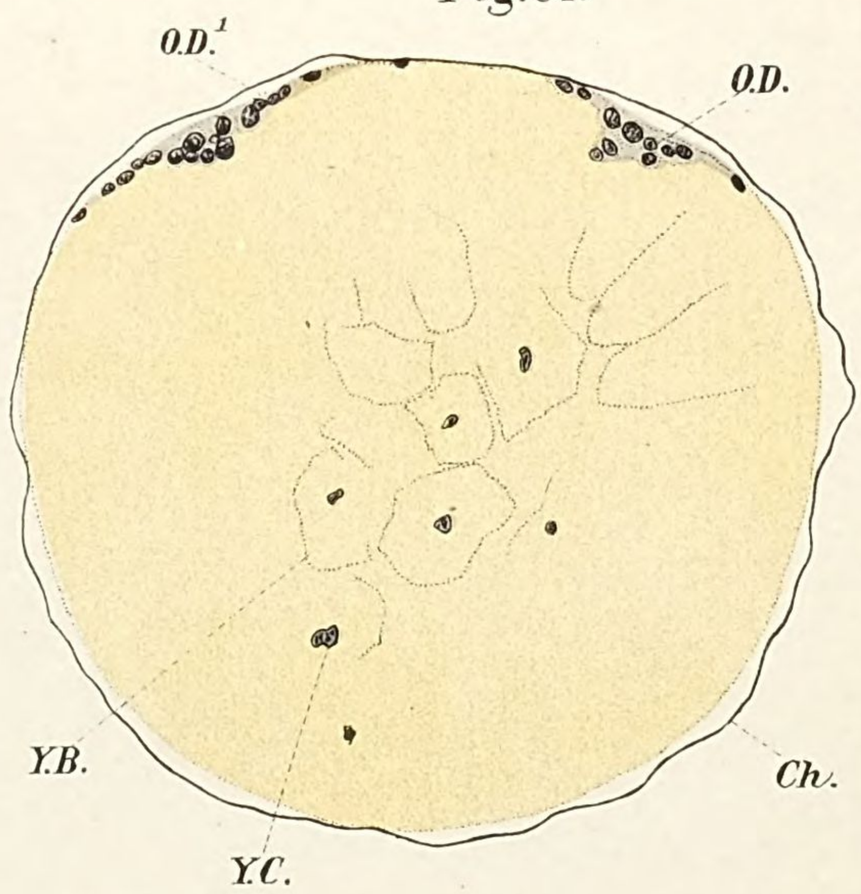


Fig.81.

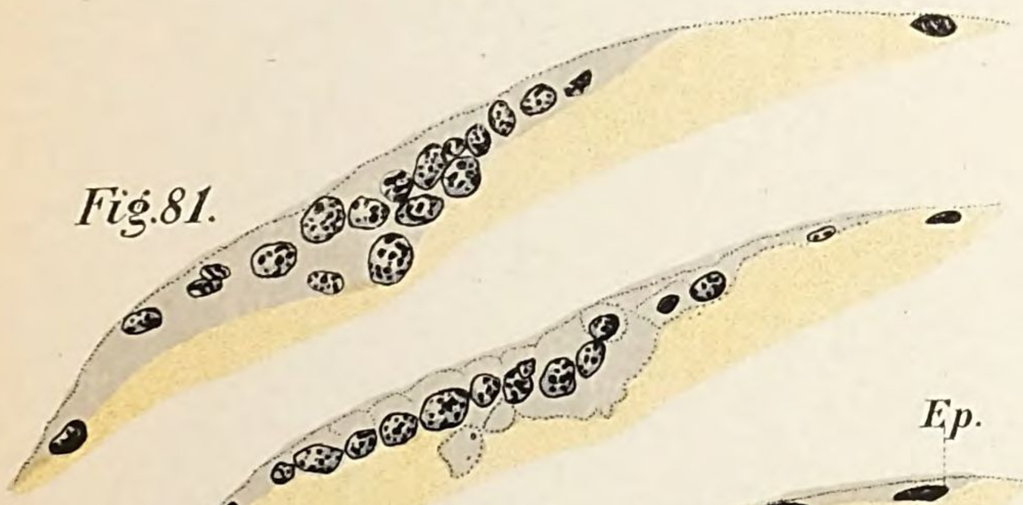
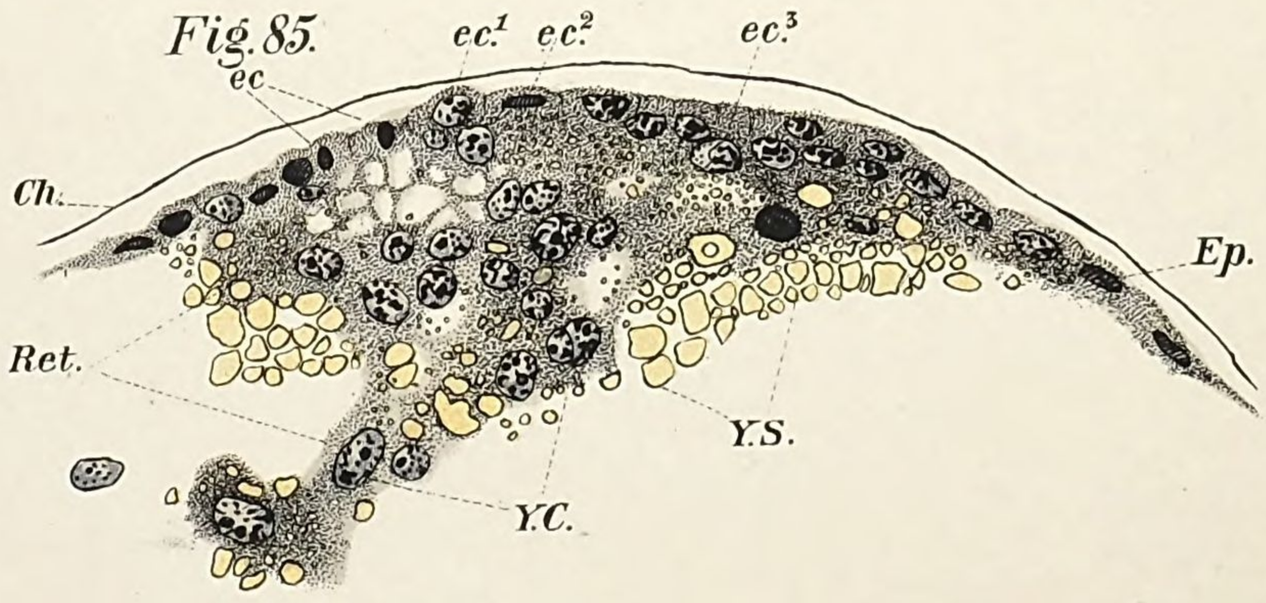


Fig.82.

Fig.83.

Fig.85.



F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS

PLATE XXXVI.

(Stage V.)

FIGS. 86, 87. Parts of longitudinal sections of embryo seven or eight hours older than that shown in Fig. 72. The optic disk (*O. D.*) is cut in Fig. 86, and in Fig. 87 its inner part is involved, with the outer border of the thoracic abdominal plate. There is no sharp demarcation between the protoplasm and the yolk, as is indicated by the dotted lines under the embryonic layers. ×291.

FIGS. 88–89. Longitudinal serial sections through the entire embryo, somewhat younger than the last, and six hours older than that represented in Fig. 72. The optic disk is sectioned in Fig. 90 through its central proliferating area (*C. M.*), and the rudiments of the three naupliar appendages appear in Fig. 89. ×115.

FIG. 91. Transverse section cutting optic disks of embryo about nineteen hours older than that of Fig. 72 and twelve hours older than that represented by Figs. 86, 87. Wandering cells (*Y. C.*[1]) have traveled to remote parts of the surface, and karyokinetic figures (*Y. C.*[2], Fig. 89) prove that they are in active division. ×115.

REFERENCE LETTERS.

A. (*I*), rudiment of first antenna.
A. (*II*), rudiment of second antenna.
Ab. P., ventral plate.
App., area of appendages.
Ch., eggshell.
C. M., proliferating area of optic disk.
ec., migrating ectoblast cell.
Ep., ectoderm.
Md., rudiment of mandible.
O. D., optic disk.
S., product of degenerating chromatin.
St. A., sternal area.
T. Cd., transverse cord.
Y. C., *Y. C.*[1–3], wandering cells.
Y. S., yolk sphere.

Fig. 86.

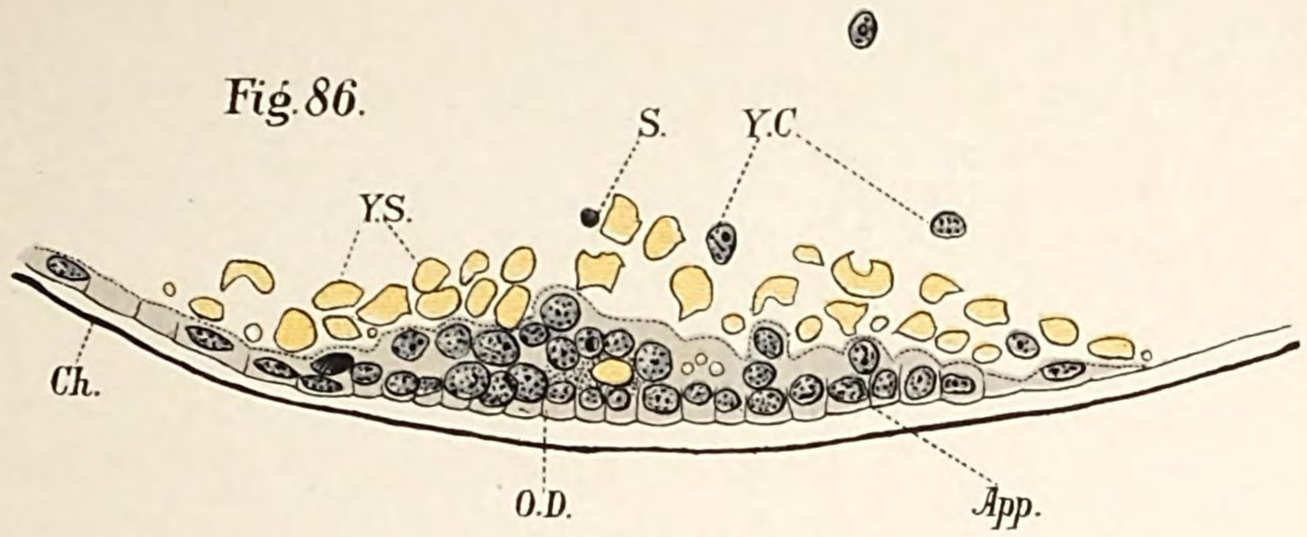


Fig. 87.

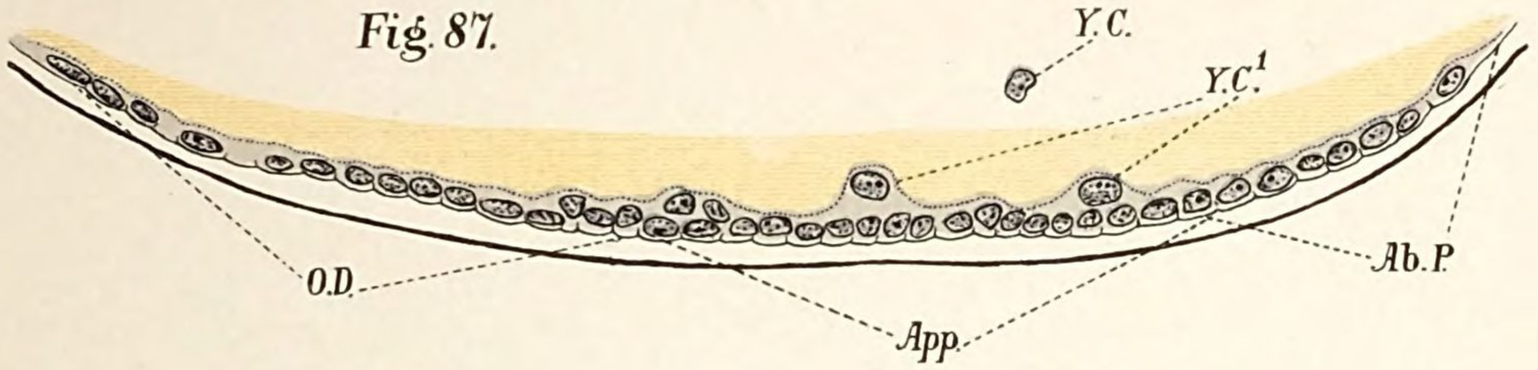


Fig. 88.

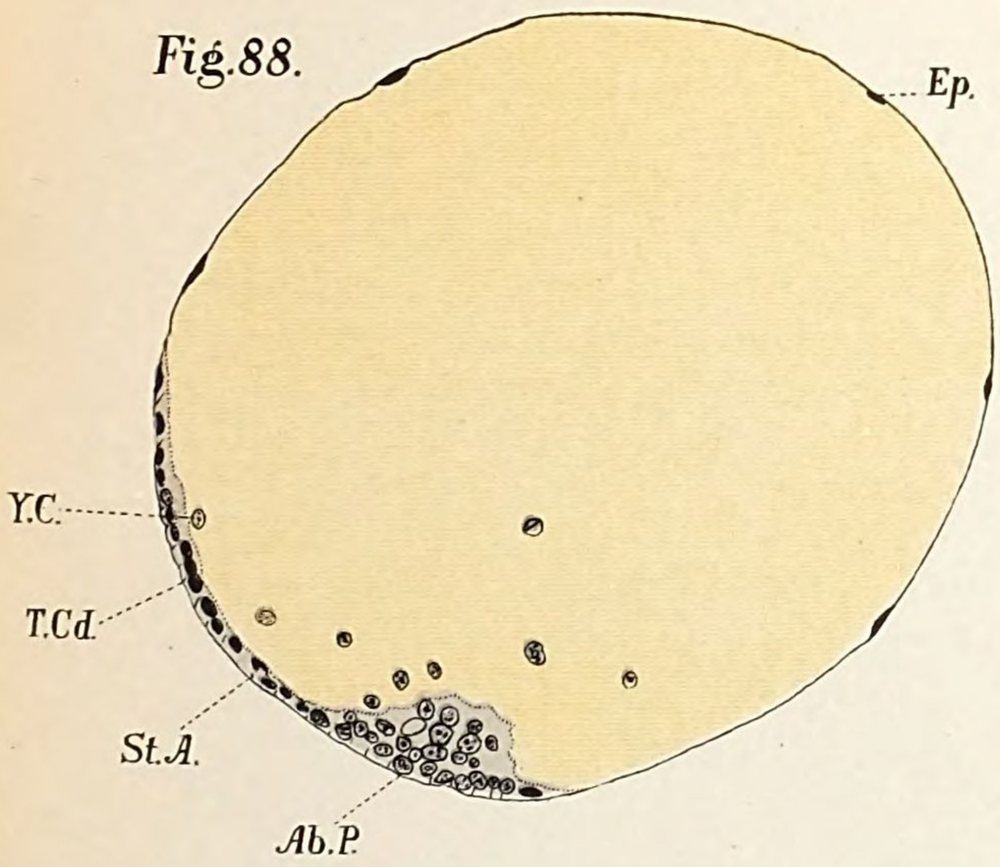


Fig. 90.

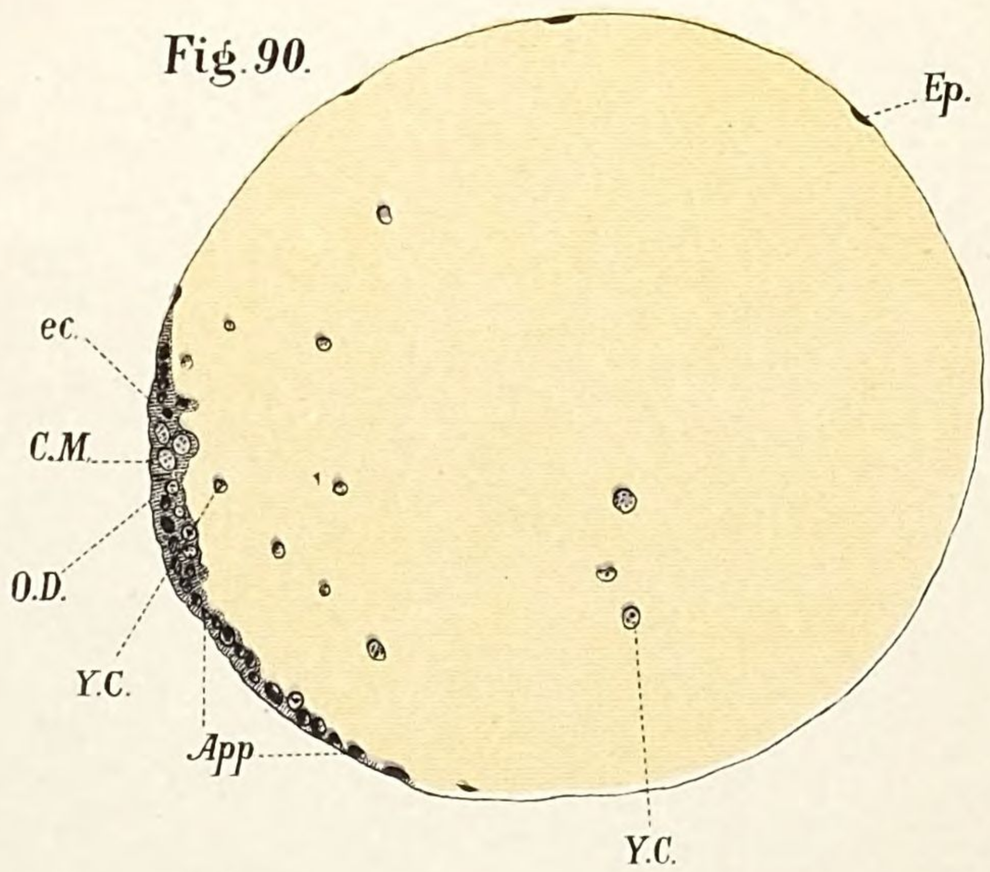


Fig. 89.

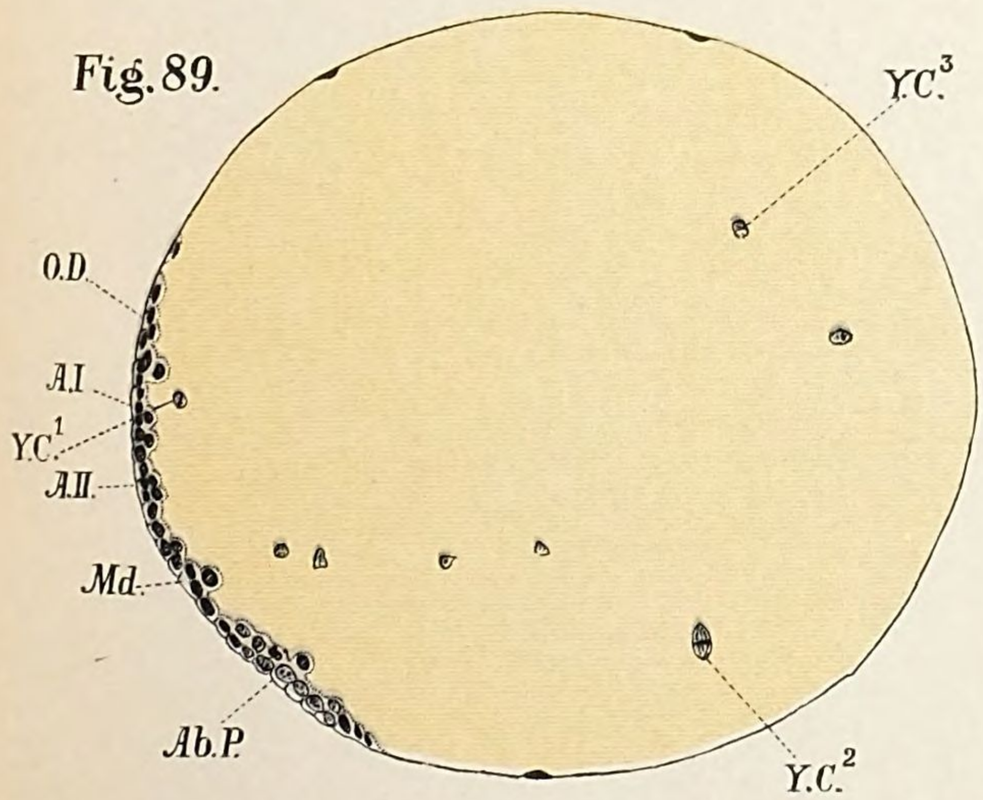
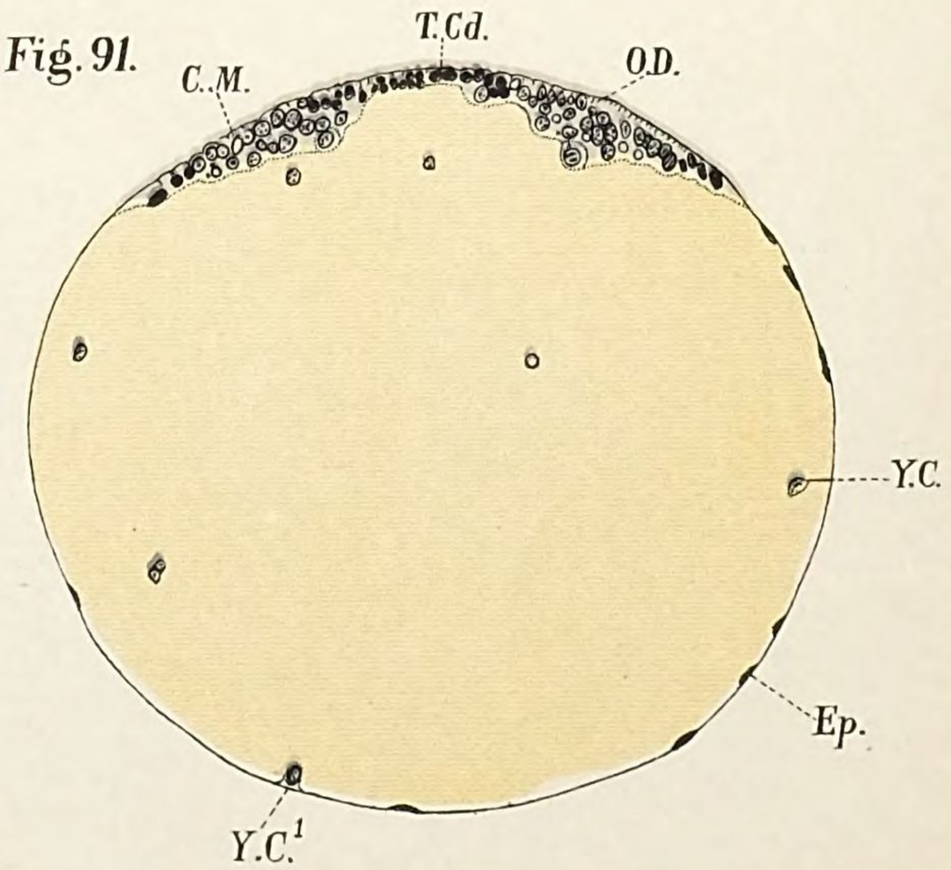


Fig. 91.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS

PLATE XXXVII.

(Stages V–VI.)

FIG. 92. Part of transverse section, showing the structure of the keel-shaped ventral plate, and indicating the origin of mesoblast from the surface of the latter. ×291.

FIG. 93. Surface view of embryo with buds of naupliar appendages. The intermediate area (*St. A.*) is covered by a single layer of ectoderm. The invagination of the mouth has not yet appeared. Some nuclei of cells which lie immediately below the surface, especially in the thoracic abdominal plate region, are represented. ×291.

FIGS. 94–95. Transverse sections of embryo, belonging to the same series as Fig. 92, to illustrate the structure of the thickening optic disks. Degenerating nuclear products (*s.*^{1}, *s.*^{2}, Fig. 95) are present, and two cells are seen delaminating side by side in Fig. 95.

REFERENCE LETTERS.

A. (*I*), rudiment of first antenna.
A. (*II*), rudiment of second antenna.
Ab. P., ventral plate.
C. M., proliferating area of optic ganglion.
Ect., ectoderm.
Md., rudiment of mandible.
Mes., wandering cells (mesoblast) attached to ectoderm.
O. G., rudiment of optic ganglion.
O. D., optic disk.
s.^{1}, *s.*^{2}, products of degenerating chromatin.
St. A., sternal area.
T. Cd., transverse cord uniting optic disks.
Y. C., wandering cell; *Y. C.*^{1}, wandering cell degenerating.

Fig. 92.

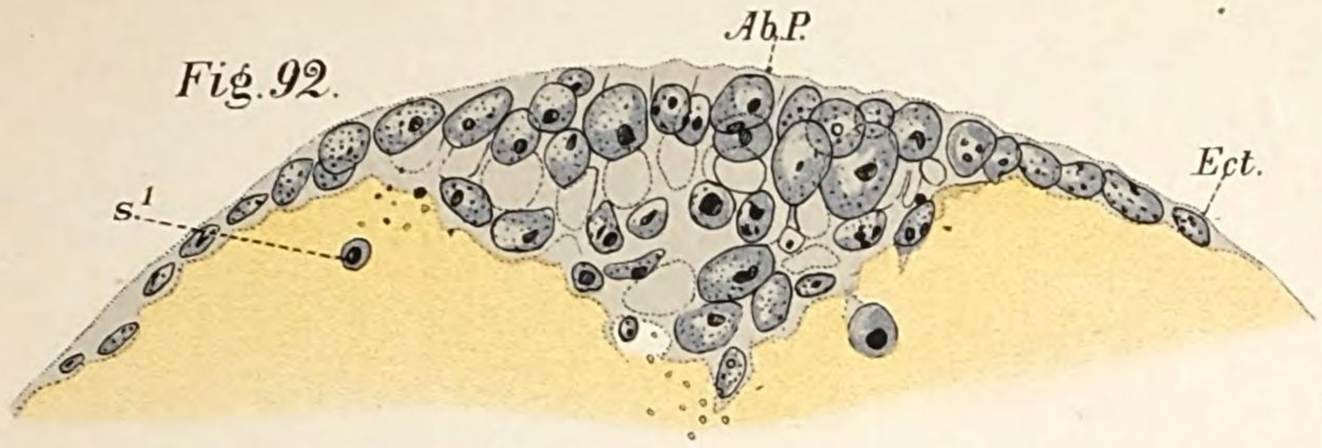


Fig. 93.

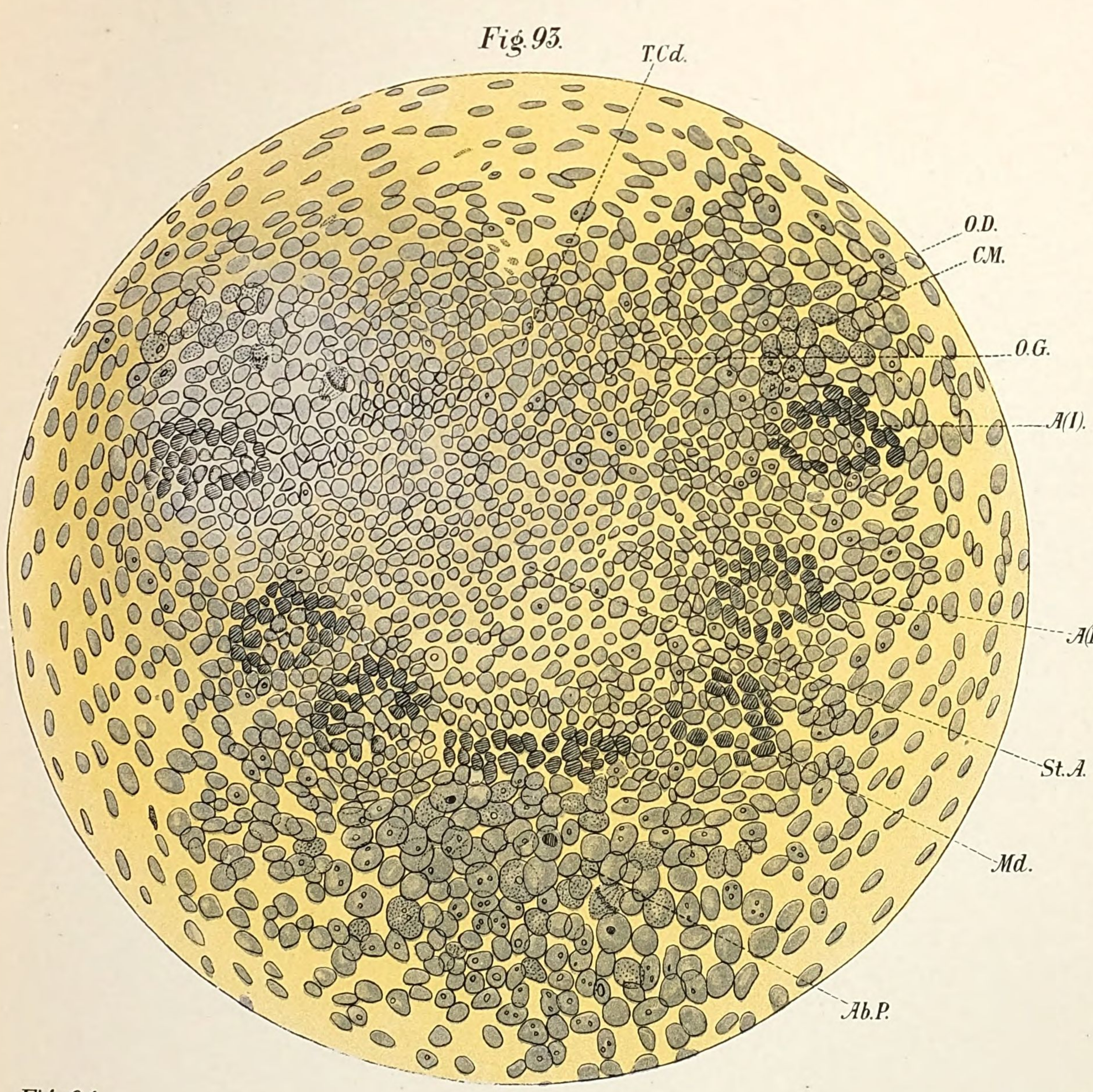


Fig. 94.

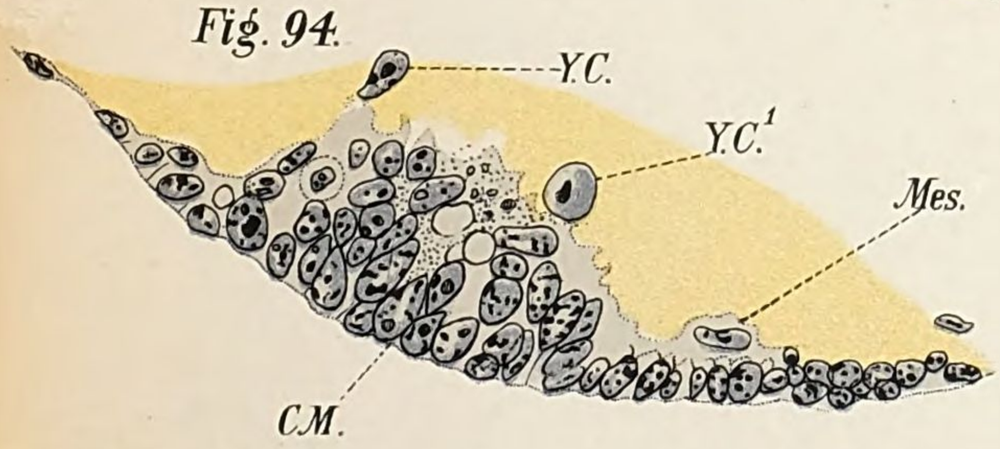
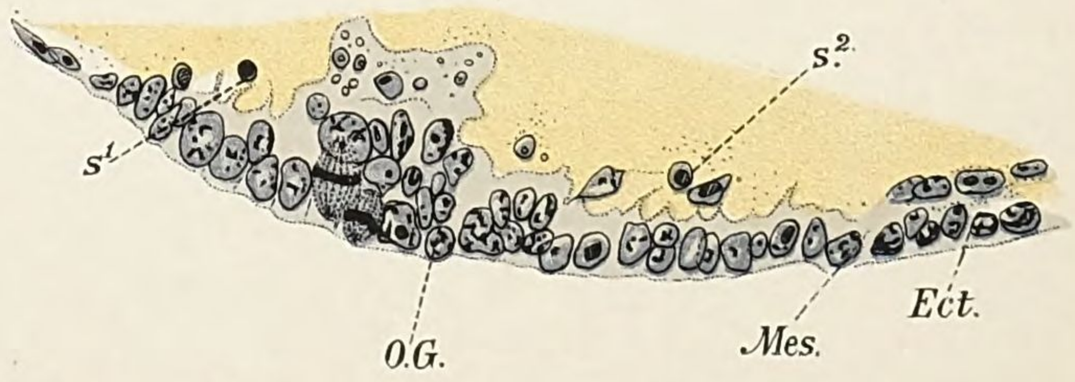


Fig. 95.



F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

Plate XXXVIII.

(Stage VI.)

Figs. 96–97. Longitudinal sections through the embryo shown in Fig. 93. The more lateral of the two, Fig. 96, cuts the middle of the optic disk, and shows the large cells of the proliferating area, one of which is caught in the act of dividing. Fig. 97 cuts the inner portion of the optic disk and the ventral plate on a level with the budding mandible (Md.). ×295.

Figs. 98–100. Longitudinal serial sections through an embryo six hours older, from the same batch of eggs. The mouth (Fig. 98, *Std.*) has already appeared. The mesoblast, formed chiefly from wandering cells, is well established on either side of the middle line of the body, and is well seen under the folds of the appendages (Fig. 100, *Mes.*) into which it extends. The mesoblast represented by the lower layers of the ventral plate is still being increased by the migration of cells from the surface of this plate, as is indicated by cell *ec.*, which is interpreted as a superficial cell about to migrate (in Fig. 98). In Fig. 100 a cell at the surface of the optic disk is in the act of delaminating. Large numbers of degenerating cells and their products are now encountered (*S. C.*, *s.*). ×295.

REFERENCE LETTERS.

A. (*I*), bud of first antenna.
A. (*II*), bud of second antenna.
Ab., *Ab. P.*, *Ad. P.*, ventral plate.
App., area of appendages.
C. M., proliferating area of optic disk.
ec., *ec.*^{1}, migrating and dividing cells at *surface* of ventral plate.
Ect., *Ep.*, ectoderm.
Md., rudiment of mandible.
Mes., mesoderm.
O. C., optic ganglion.
O. D., optic disk.
s., *s.*$^{1-2}$, products of degenerating chromatin.
S. C., *S. C.*$^{1-2}$, cells in various stages of degeneration.
St. A., sternal area.
Std., stomodæum.
T. Cd., Transverse sheet of ectoderm uniting optic disks.
Y., *Y. S.*, yolk spheres.

Fig. 96.

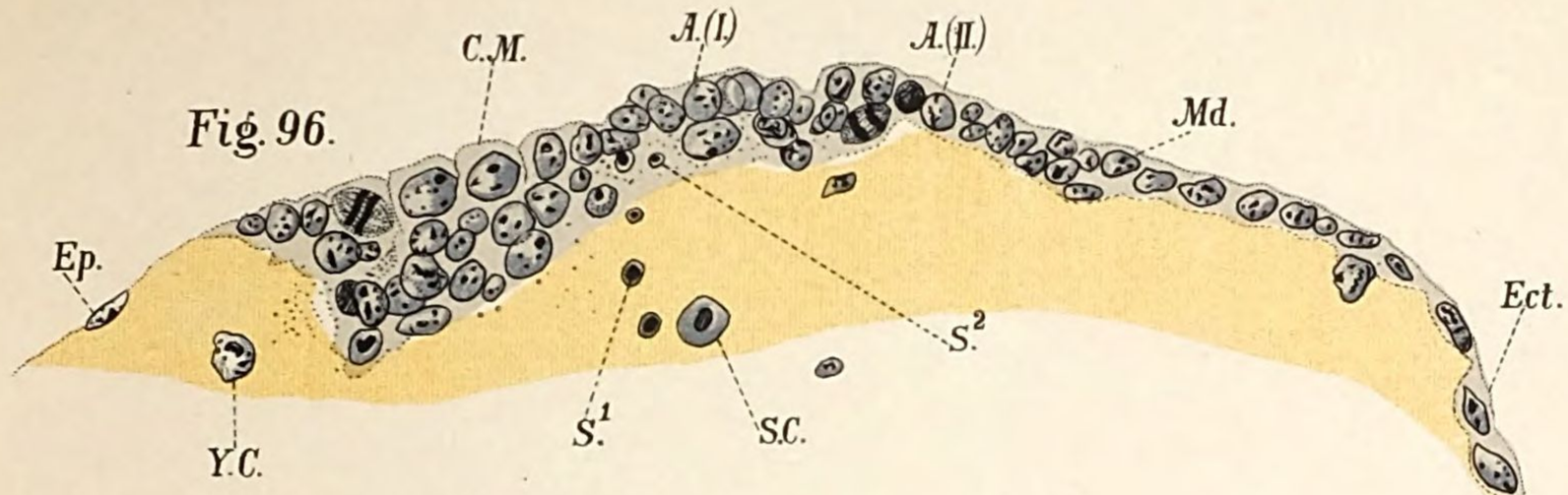


Fig. 97.

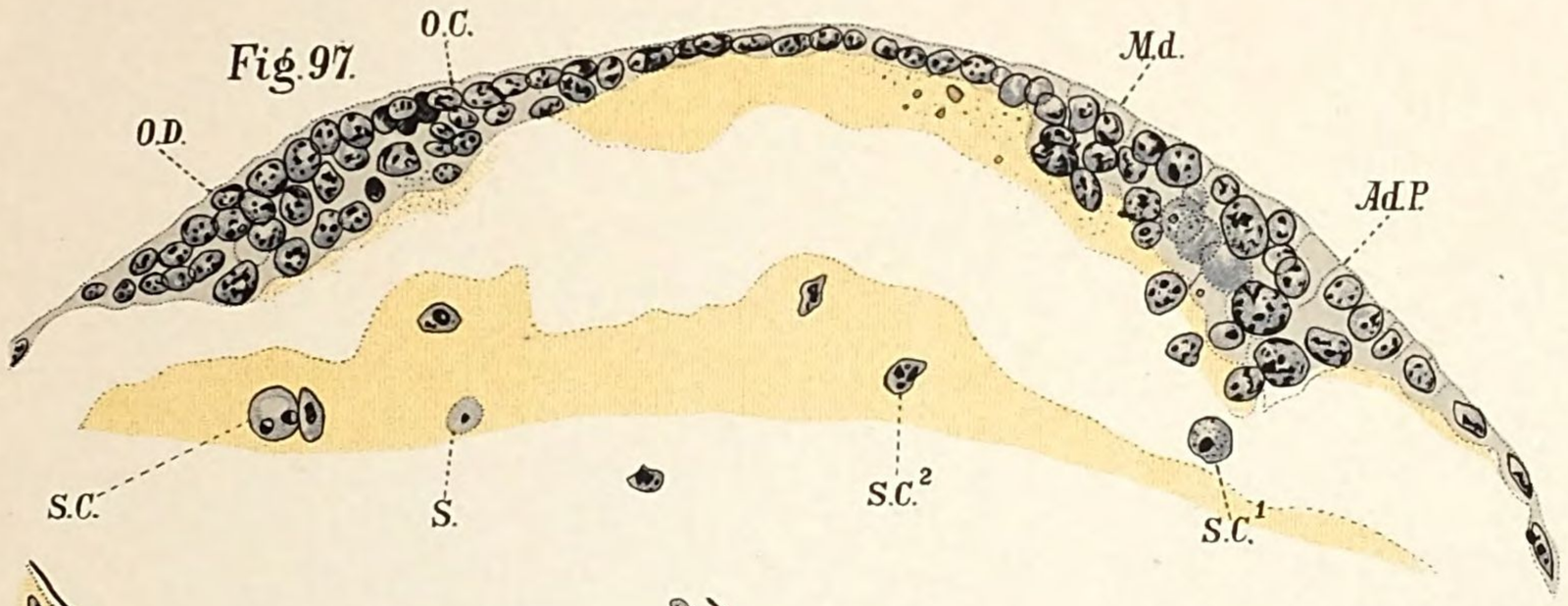


Fig. 98.

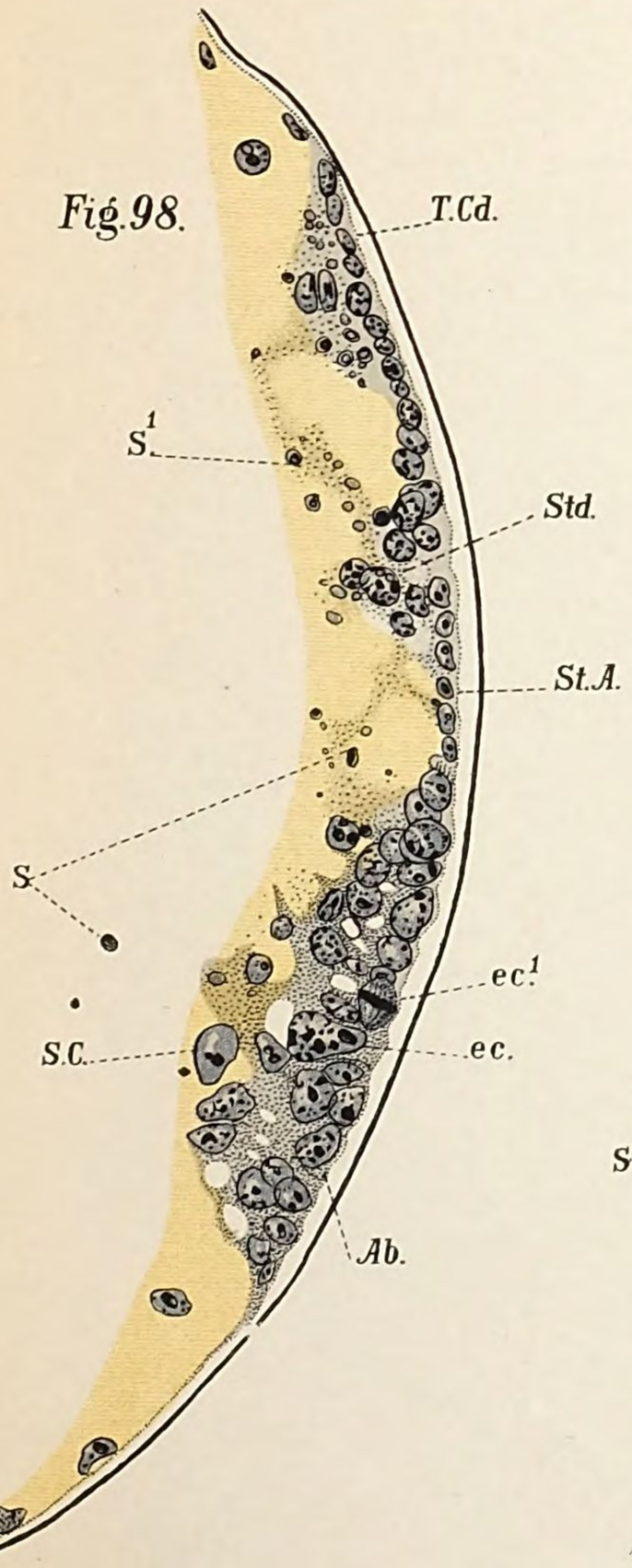


Fig. 99.

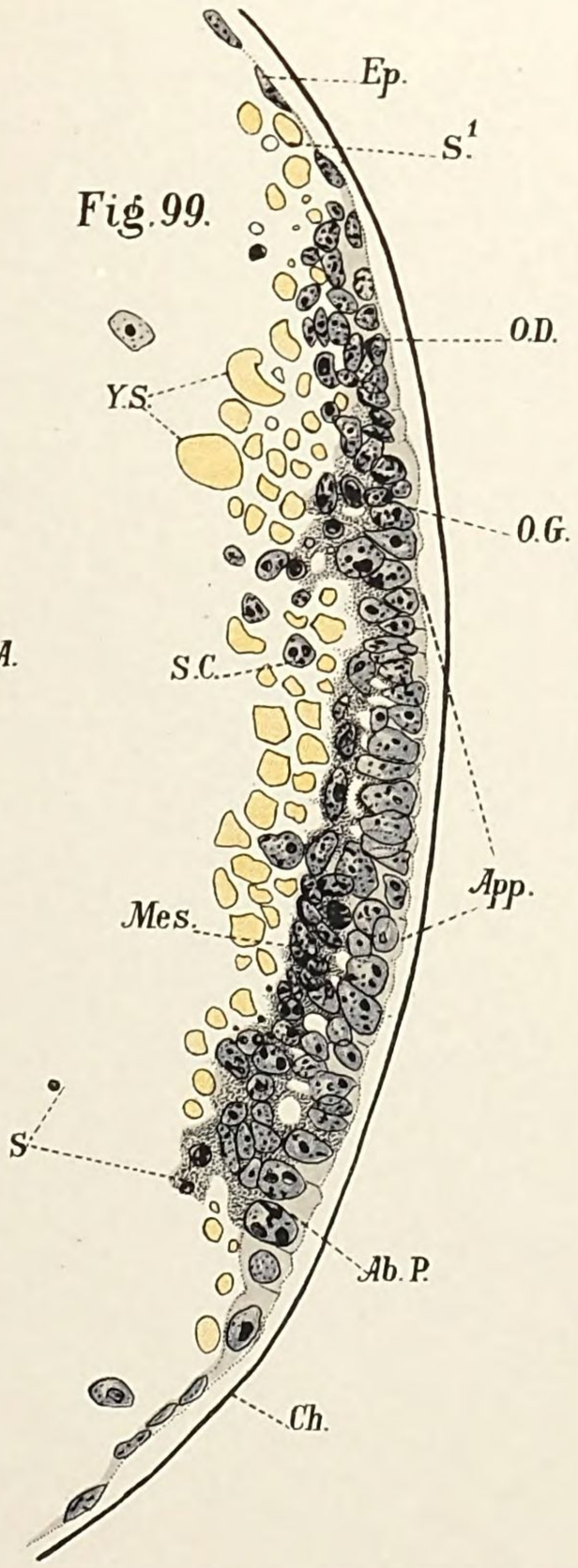
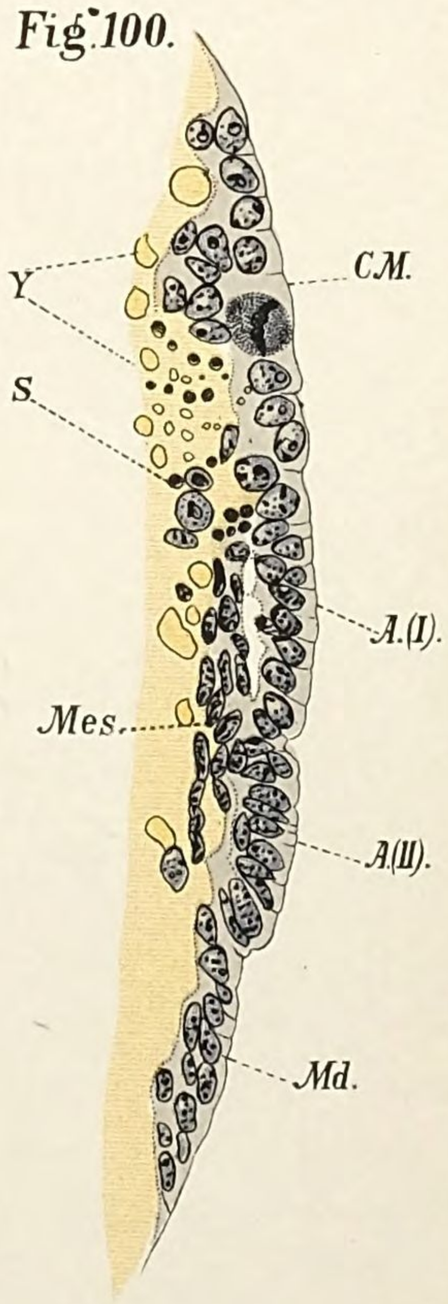


Fig. 100.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS

PLATE XXXIX.

(Stage VI.)

FIGS. 101–105. Serial longitudinal sections of early nauplius embryo, twelve and one-half hours older than that represented by Figs. 98–100, Pl. XXXVIII, and eighteen and one-half hours older than the stage represented in Fig. 93, Pl. XXXVII. The thoracico-abdominal fold or papilla is now forming, apparently by the ingrowth of the surface ectoblast (Fig. 104, *Ab. C.*). Fig. 102 is exceptionally favorable in showing the undoubted delamination of two cells standing side by side at the surface of the optic disk (*ec.*). The common radial division of the ectoderm of the thoracico-abdominal region and other parts is illustrated by the cell *ec.*[1] of the same section. Fig. 105 cuts the straight tubular stomodæum. ×295.

FIG. 106. Longitudinal median section of embryo several hours older than the last. A deep, narrow, transverse furrow (*Ab. C.*) now abruptly separates the thoracico-abdominal papilla from the sternal area lying between it and the stomodæum. ×291.

FIG. 107. Transverse section through the optic disks, from same stage. Cell delamination in this region is again met with. ×291.

FIG. 108. Longitudinal lateral section through entire egg, showing the distribution of wandering cells, and the relations of the embryo to the ovum. The eggshell is unnaturally distended. An inner molted membrane is present, as is better shown in Fig. 106 and Fig. 104, *Mb.*

In Fig. 108 a large cell is seen at the surface, and below this a large cell followed by a row of similar cells. The first two cells possibly represent a budding ectoblast and mesoblast, and the rows of cells at the surface and below it are possibly derived from them. ×115.

REFERENCE LETTERS.

A. (*I*), bud of first antenna.
A. (*II*), bud of second antenna.
Ab., thoracico-abdominal papilla.
Ab. C., transverse superficial furrow by which fold of the thoracico-abdominal process is formed.
A. Y. S., products of degenerating chromatin.
B. Z., budding zone.
Ch., eggshell.
C. M., proliferating area of optic disk.
Ct. S., cells on ventral side of yolk next to optic disks, probably representing mesoblast derived from wandering cells.
ec., *ec.*[1], dividing ectoblastic cells.
Ect., *Ep.*, ectoderm.
M., wandering cell at surface behind thoracico-abdominal fold (Fig. 108).
Mb., embryonic molt.
Md., rudiment of mandible.
Mes., mesoblast.
O. D., optic disk.
O. G., optic ganglion.
O. S. G., brain.
Pd., proctodæum.
S., *S.*[1–2], products of degenerating chromatin.
S. C., degenerating cells.
St. A., sternal area.
Std., stomodæum.
Y., *Y. S.*, yolk.

Fig.101.

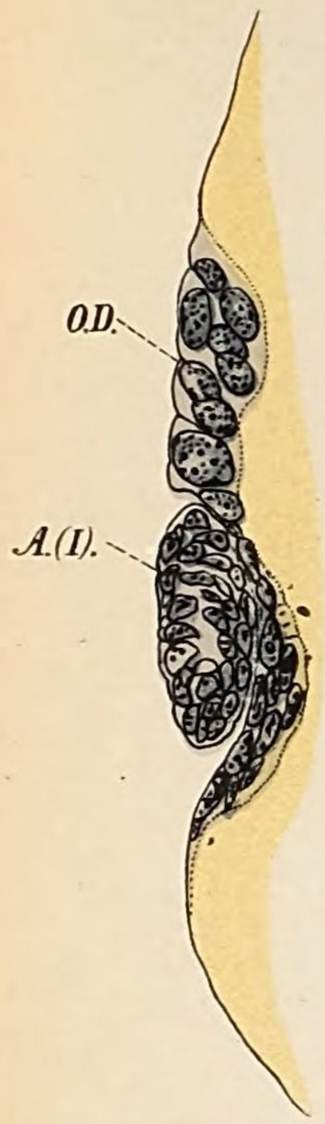


Fig.102.

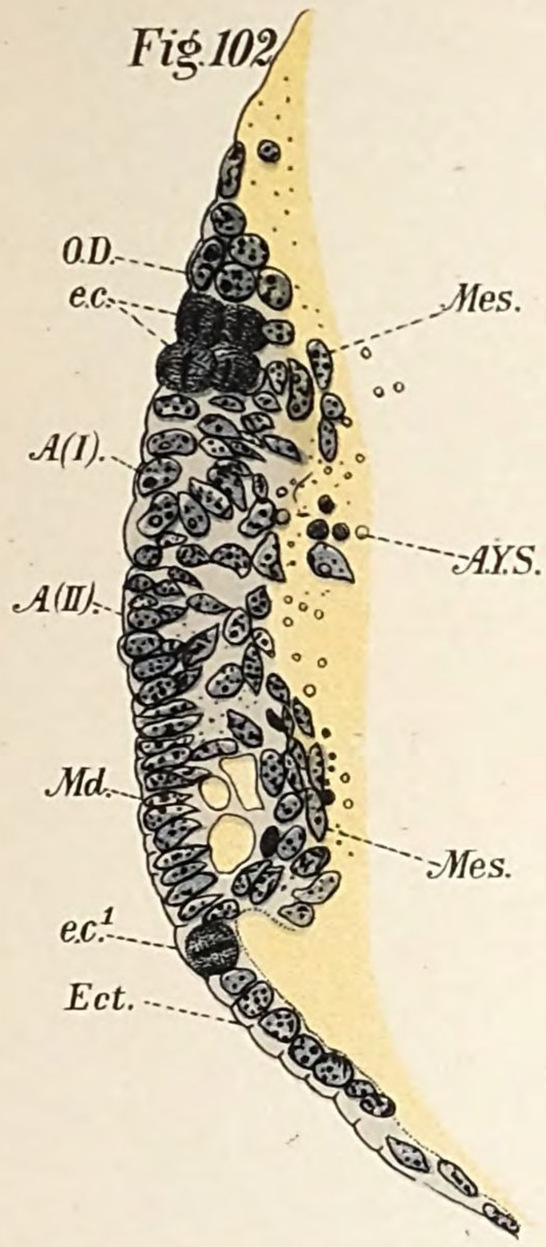


Fig.103.

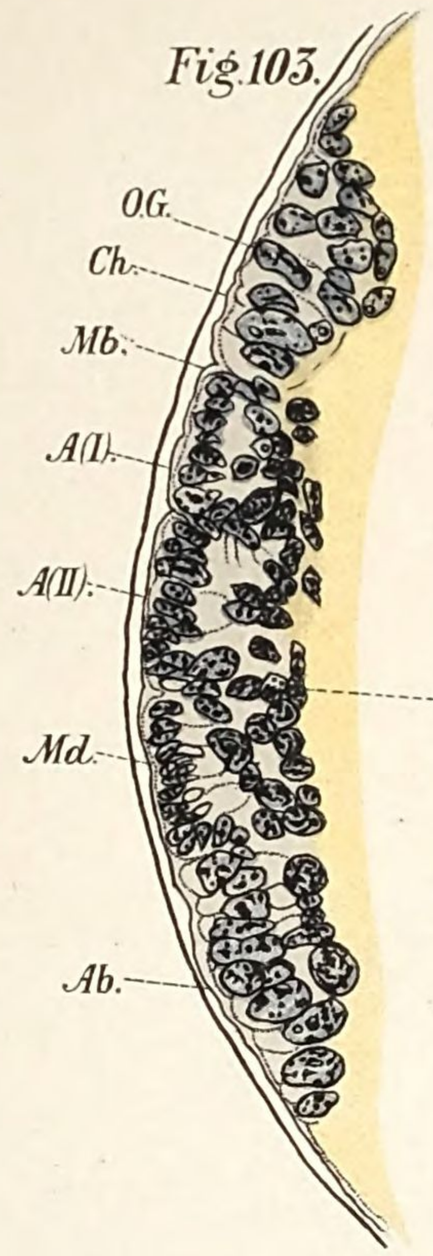


Fig.104.

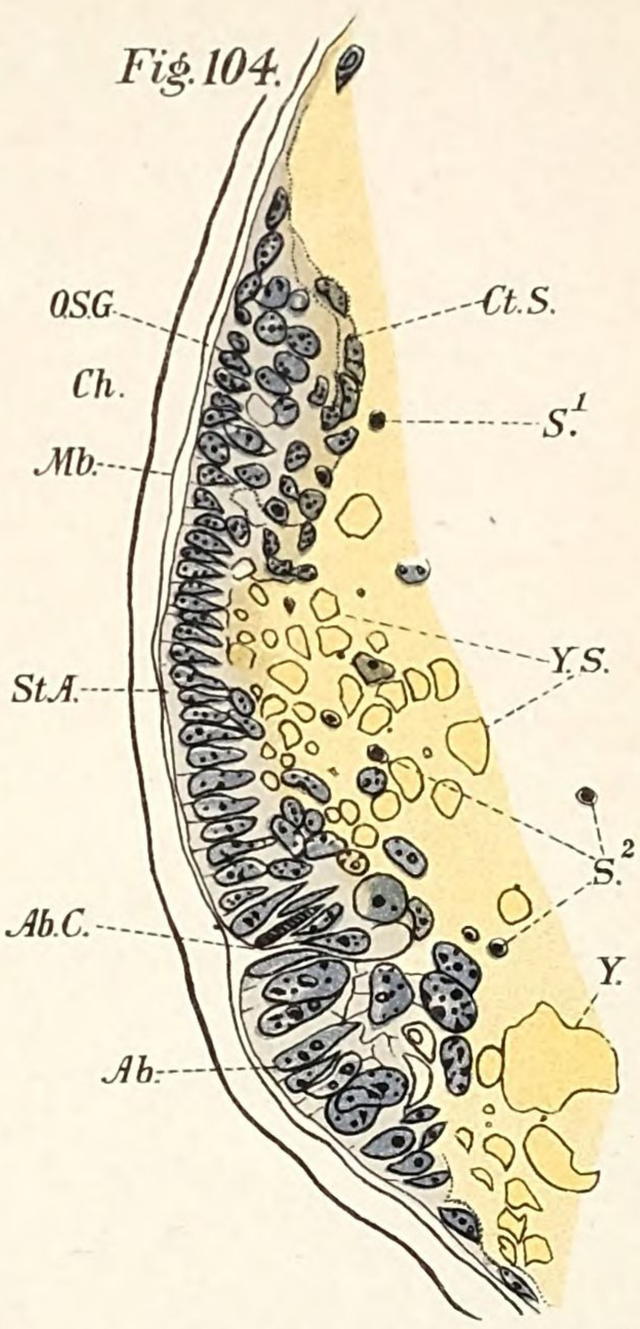


Fig.105.

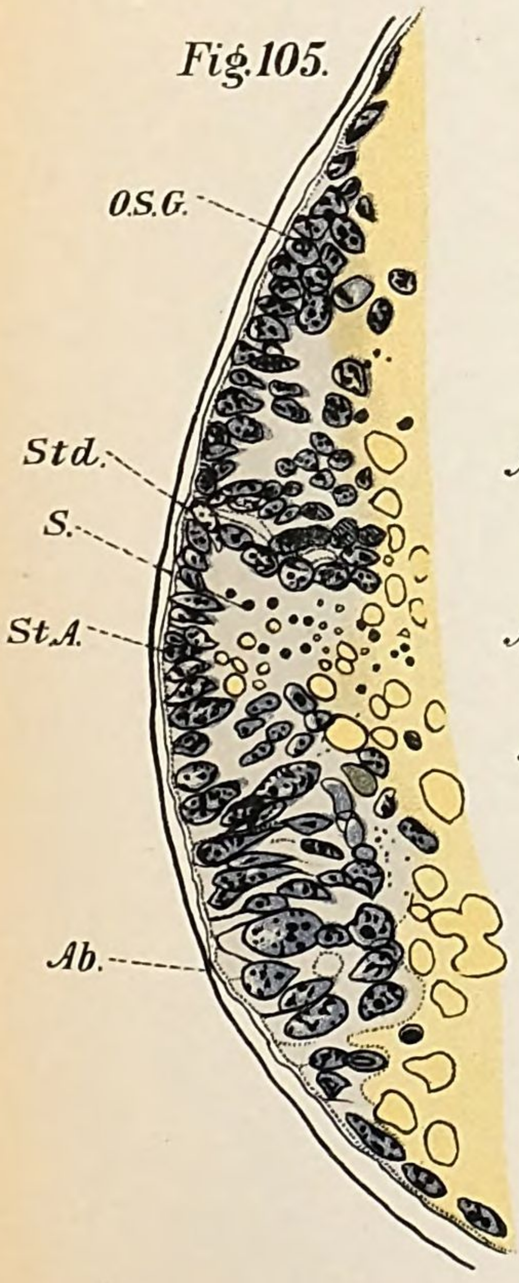


Fig.106.

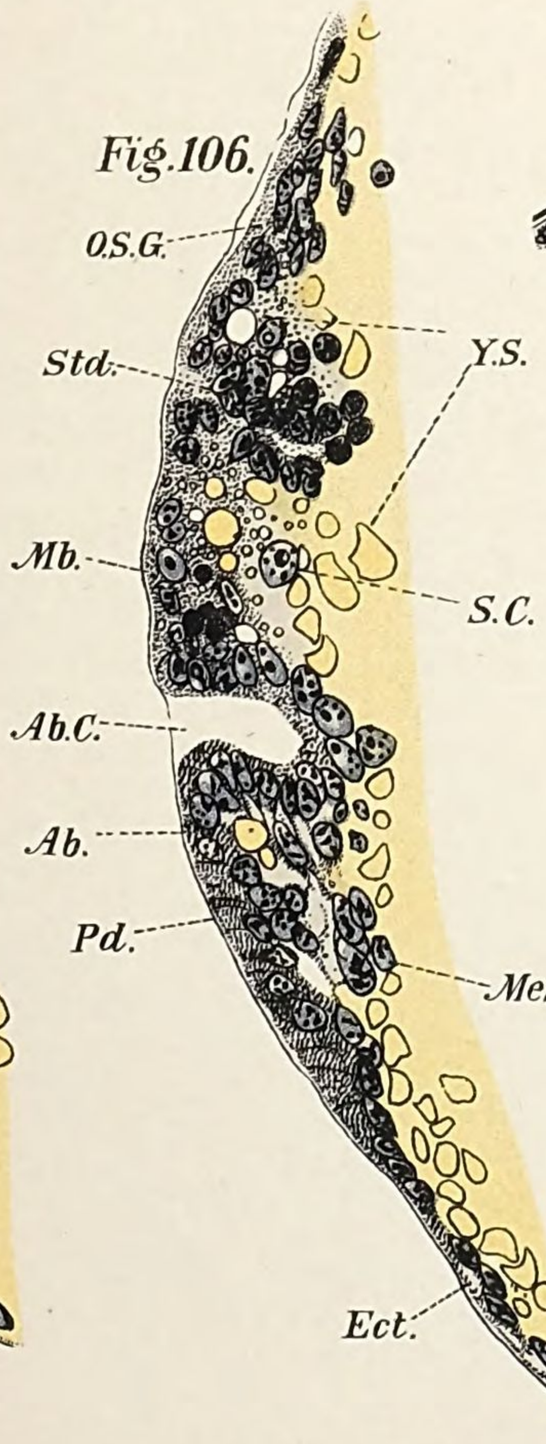


Fig.107.

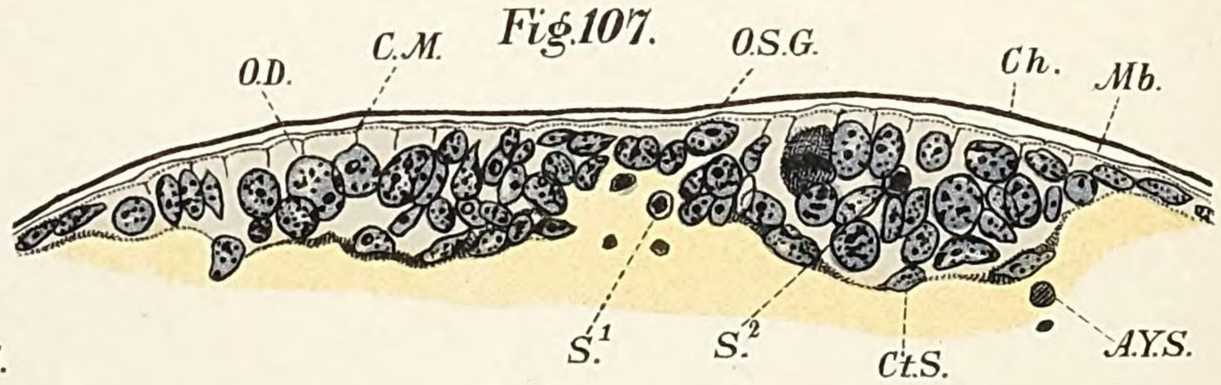
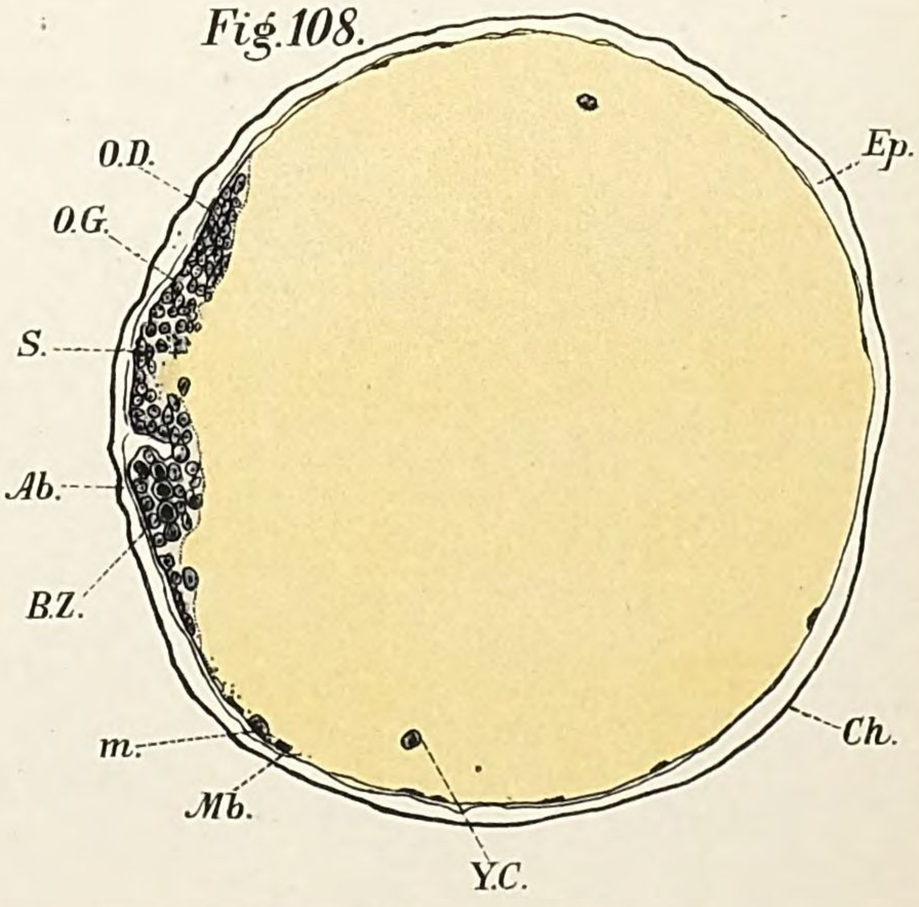


Fig.108.



F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

PLATE XL.

(Stage VI.)

FIG. 109. Sketch of egg-nauplius. Anus not so clearly seen in surface view, as represented in this and the following figure. Mouth on a level with antennules. ×72.

FIG. 110. Sketch of older embryo. Appendages all bending backwards and inwards toward middle line. ×72.

FIG. 111. Egg-nauplius less developed than shown in Fig. 109, but from same batch of eggs. The position of the mouth, which is post-antennal from the first, is now on the middle line between the antennæ and the antennules. The probable position of the anus is indicated, but it could not be clearly seen. The bud which represents the endopodite of the antenna is just appearing on the right side. ×157.

FIG. 112. Oblique transverse section, through egg-nauplius of a common shore crab of Beaufort, North Carolina, probably *Sesarma*. ×286.

FIG. 113. Median longitudinal section, through a similar embryo. The egg membranes are not naturally shown. The yolk is diagramatically represented. Wandering cells occur in it (*Y. C.*), and in Fig. 113 degenerative products (*Deg.*) are met with. ×286.

REFERENCE LETTERS.

A., anus.
A. (*I*), antennal bud.
A. (*I*), antennular bud.
Ab., thoracico-abdominal fold.
Ch., eggshell.
Deg., degenerative cell products.
Ep., ectoderm.
Gl., ectoblast of neural plate.
H., mesoblast cells, forming rudimentary heart.
Hg., hind gut.
Lb., labrum.
Md., mandibular bud.
Mes., mesoblast below surface.
O. G., optic ganglion.
O. L., optic lobe.
O. S. G., *S. O. G.*, rudimentary brain.
Std., stomodæum.
Vac., vacuole.
Y. C., wandering cells.

Numbers 114–125 mark the planes of the transverse and longitudinal sections represented on Pls. XLI–XLIII.

Fig.109.

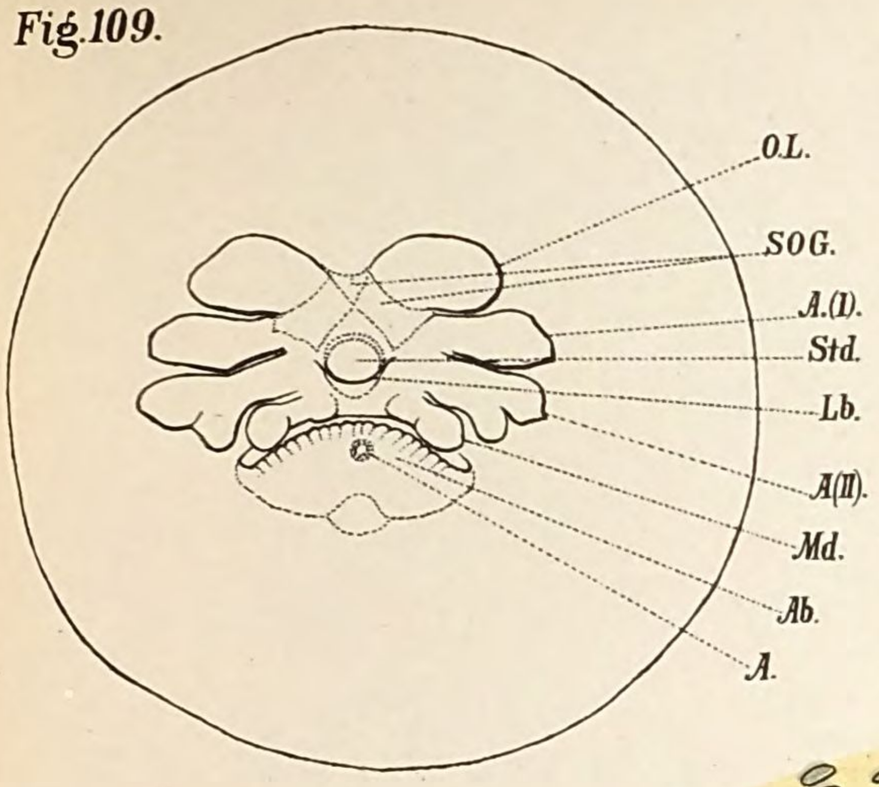


Fig.110.

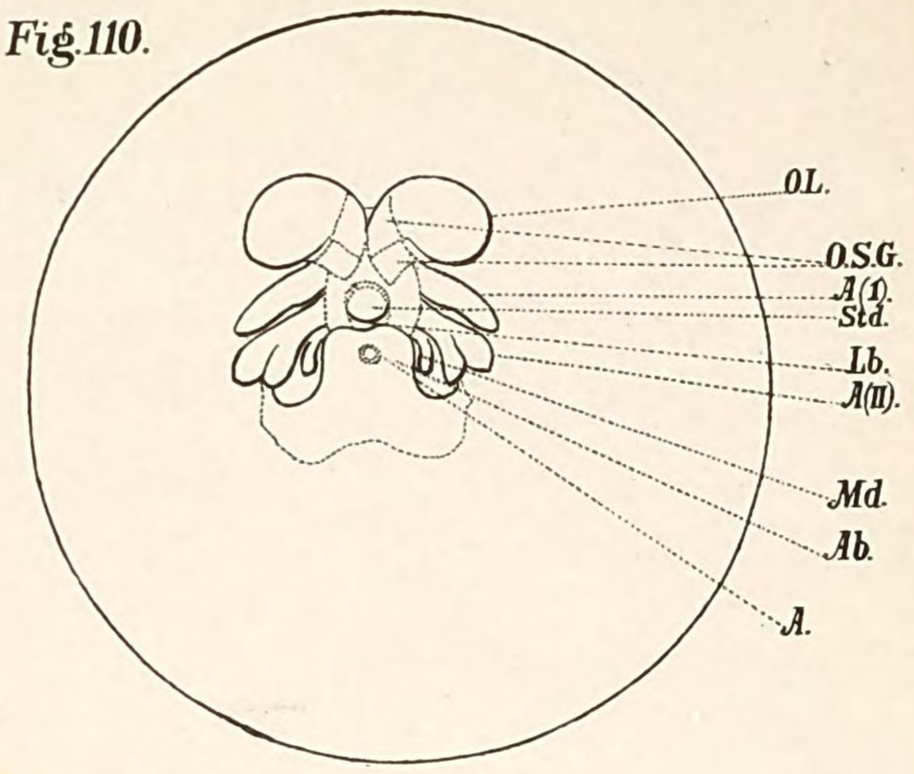


Fig.111.

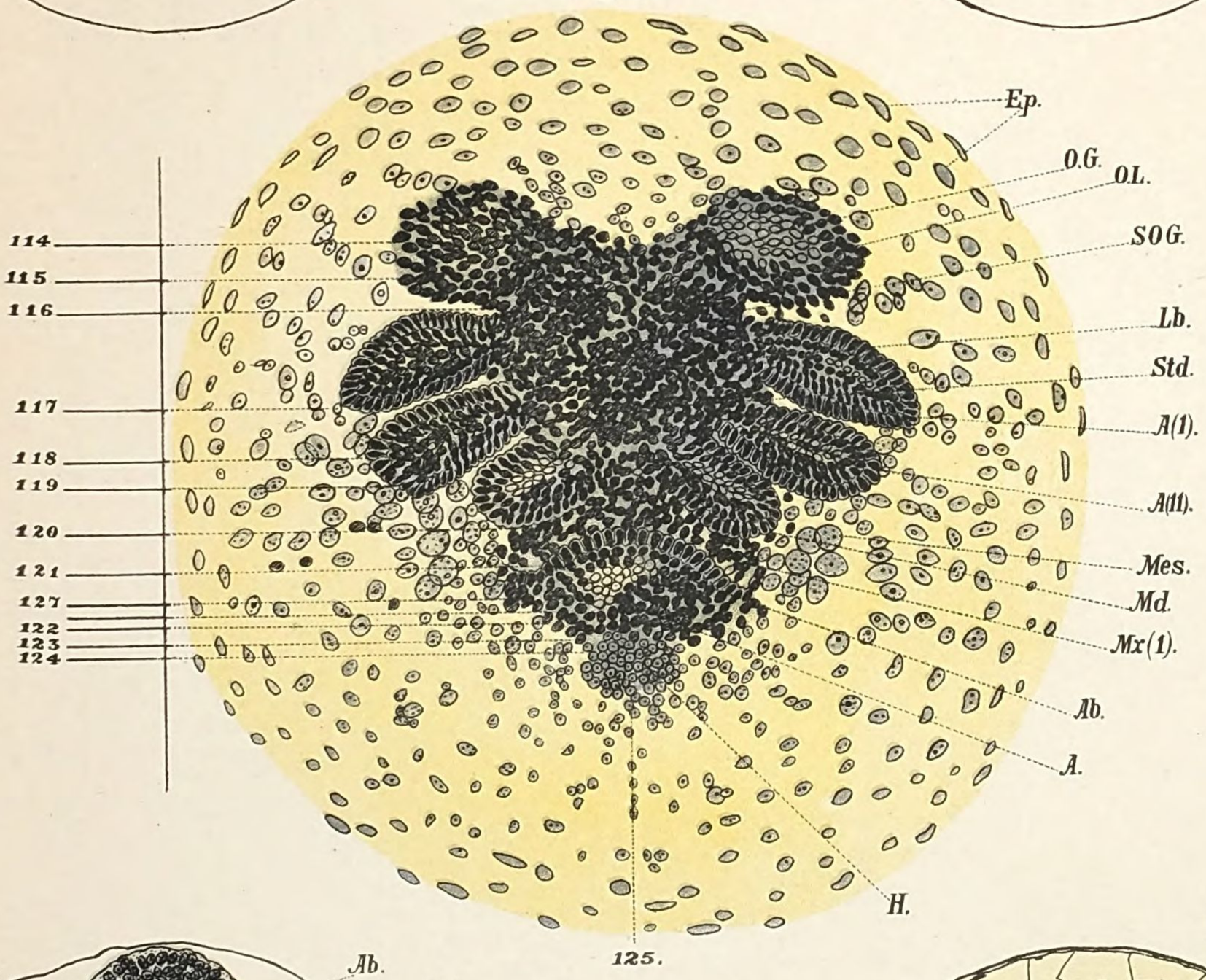


Fig.112.

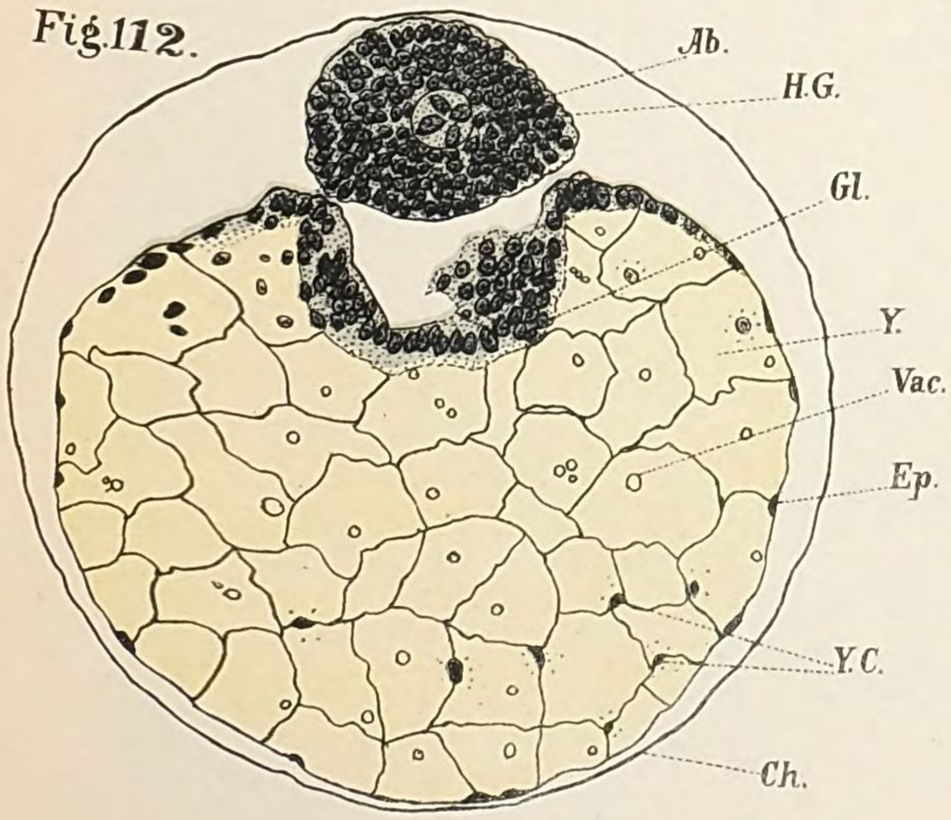
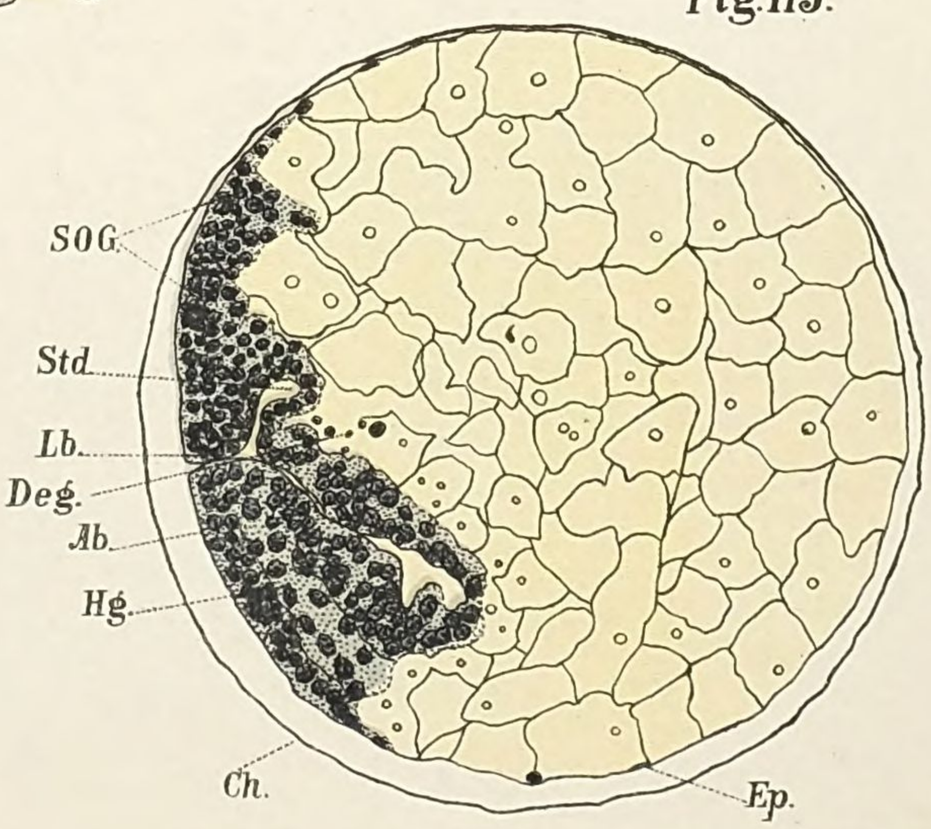


Fig.113.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS AND SESARMA?

PLATE XLI.

(Stage VI.)

FIGS. 114–118. Transverse serial sections of egg-nauplius in stage shown in Fig. 109. Plane of section indicated in Fig. 111, which is from an embryo a trifle less advanced. The lobular condition of the enlarged optic disks is well shown in Figs. 114, 115. In Fig. 114 a delaminating cell (*ec.*) at the surface of the optic lobe is cut, and in Fig. 115 a superficial ectodermic cell next the brain is dividing perpendicularly. The intimate fusion of the brain and the optic ganglion is seen in Figs. 115, 116. Fig. 117 cuts the stomodæum passing through the mouth and the antennæ. Mesoblast is already well established in the pockets of all the appendages, as indicated at an earlier period. Degenerating cell products (*S.*, *A. Y. S.*, Fig. 18) are very abundant in the region of the stomodæum, and occur also in the appendages (*S.*–*S.*[1], *S. C.*, Fig. 118). ×291.

REFERENCE LETTERS.

A. (*I*), antennal bud.
A. (*II*), antennular bud.
A. Y. S., alteration products of yolk.
Ct. S., cells partially covering brain, derivatives from yolk-wandering cells.
ec., surface cell of ectoderm dividing horizontally.
Ect., *Ep.*, ectoderm.
Md., mandibular bud.
Md. G., mandibular ganglion.
M. F., median furrow.
O. G., optic ganglion.
O. L., optic lobe.
Ret., protoplasmic reticulum.
S. S.[1], products of cell degeneration.
S. O. G., brain.
Std., stomodæum.
Vac., vacuole.
Y., *Y. C.*, yolk.

Fig.114.

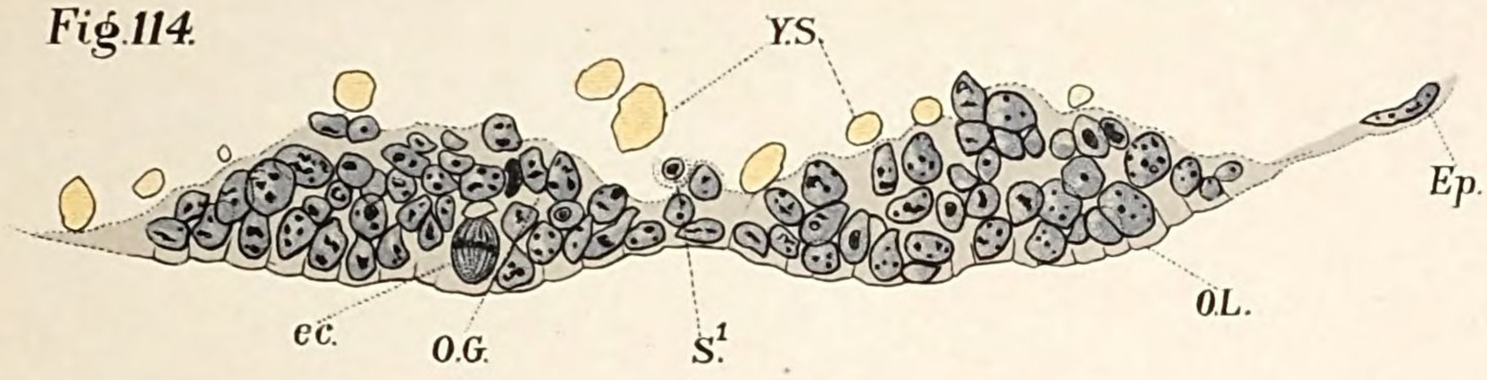


Fig.115.

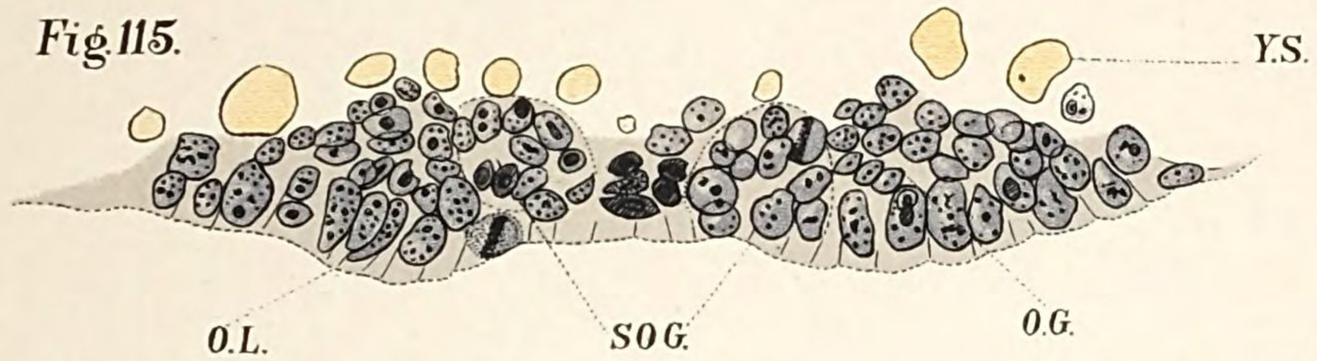


Fig.116.

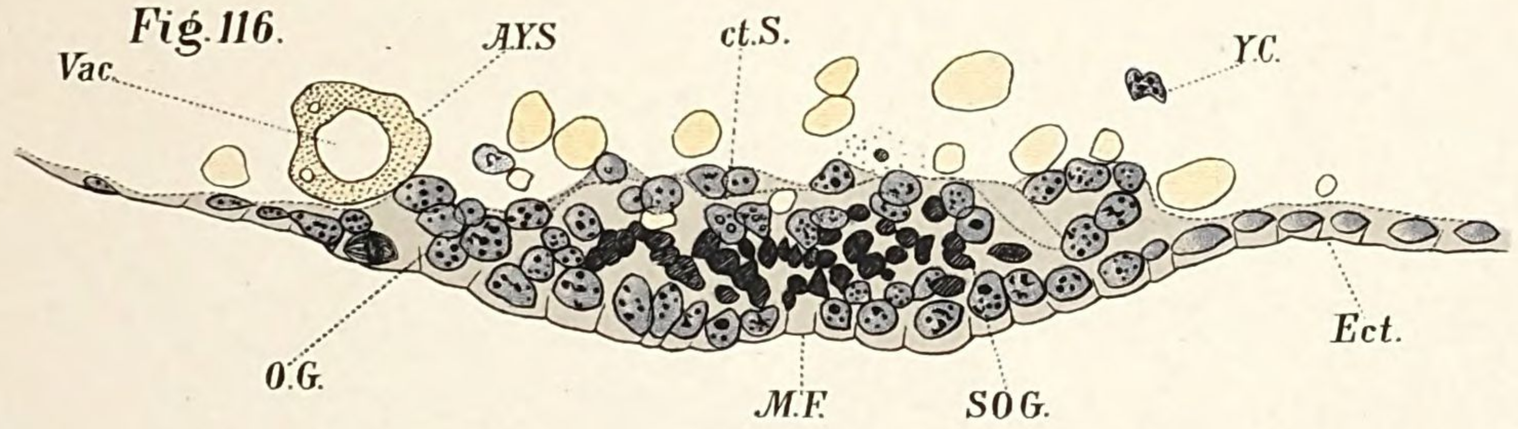


Fig.117

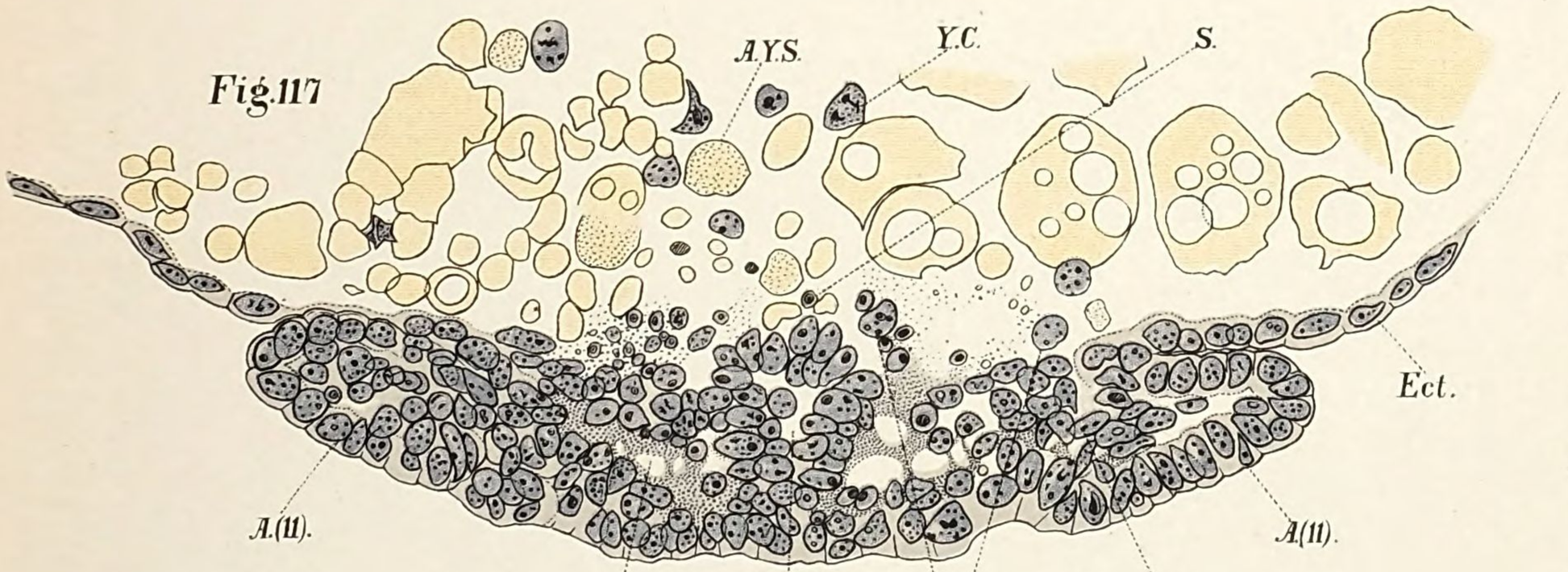
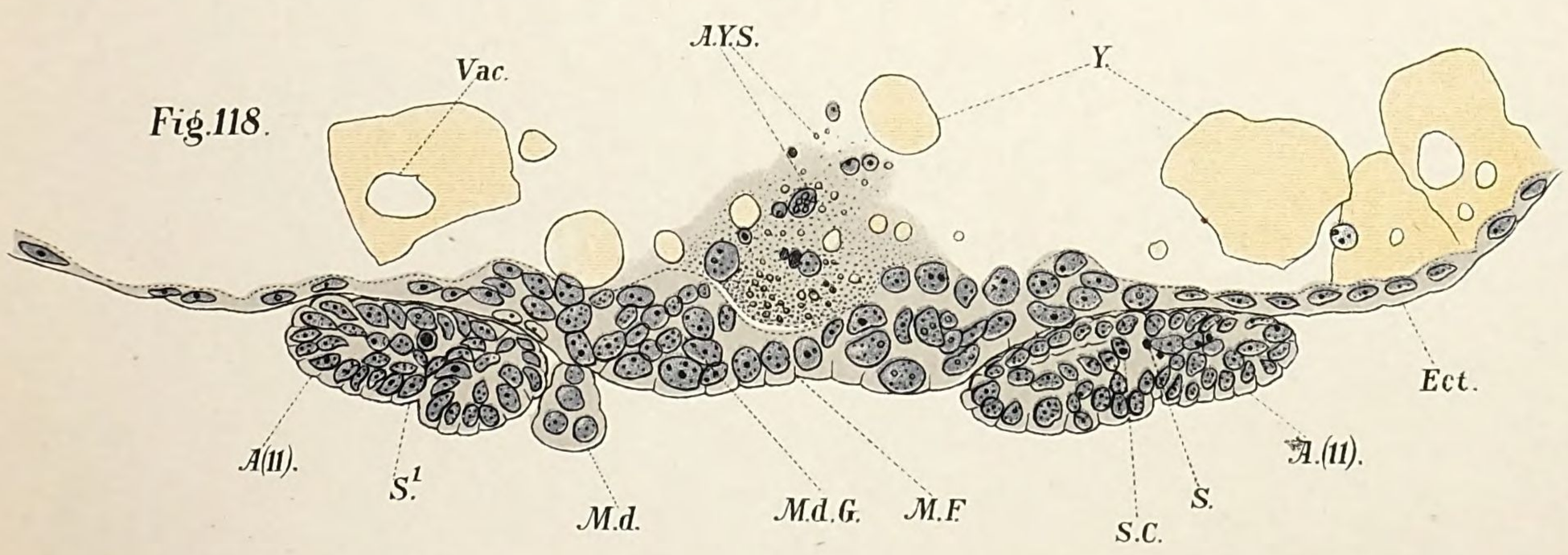


Fig.118.



F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS SAULCYI.

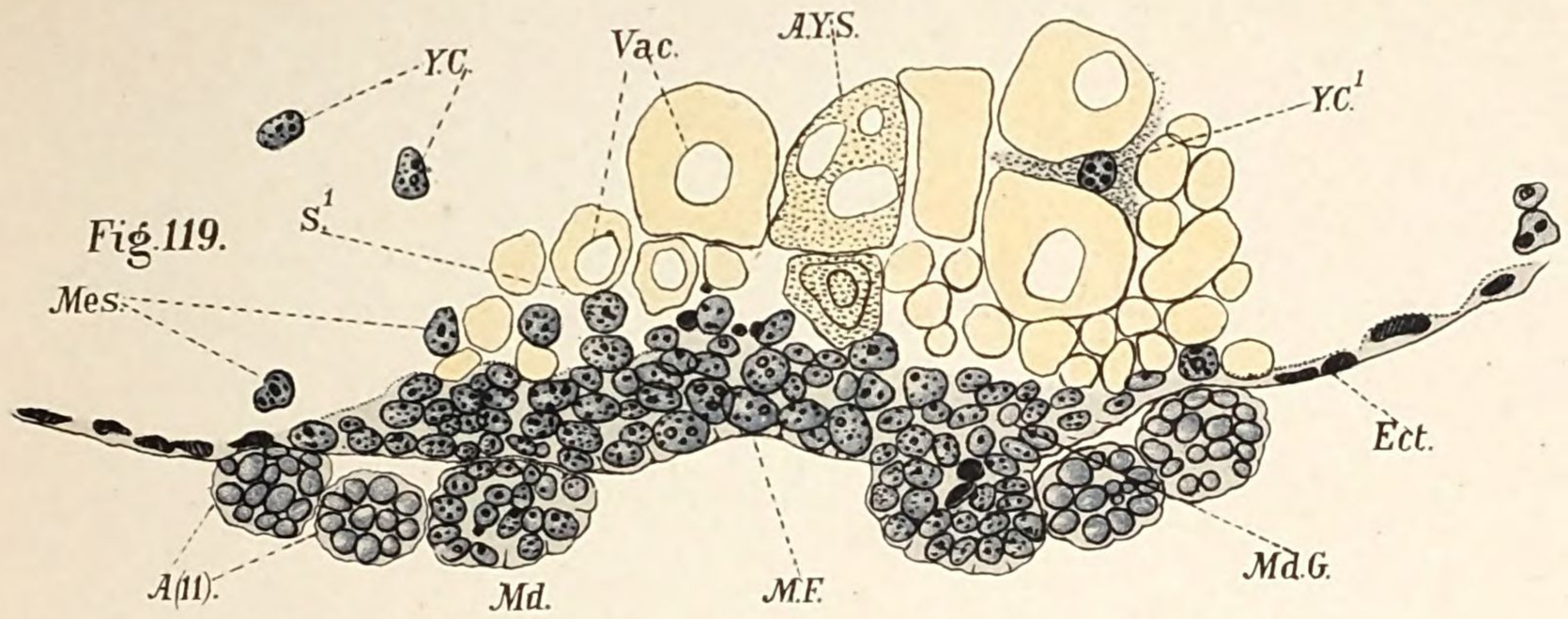
PLATE XLII.

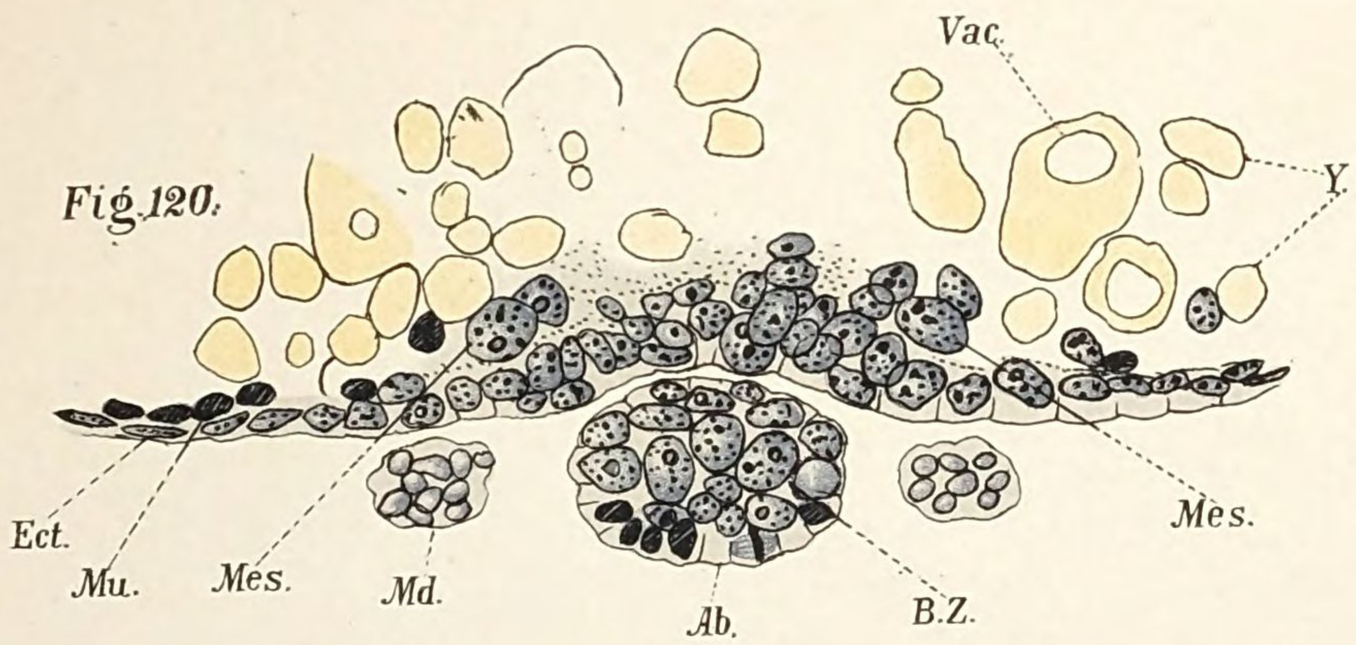
(Stage VI.)

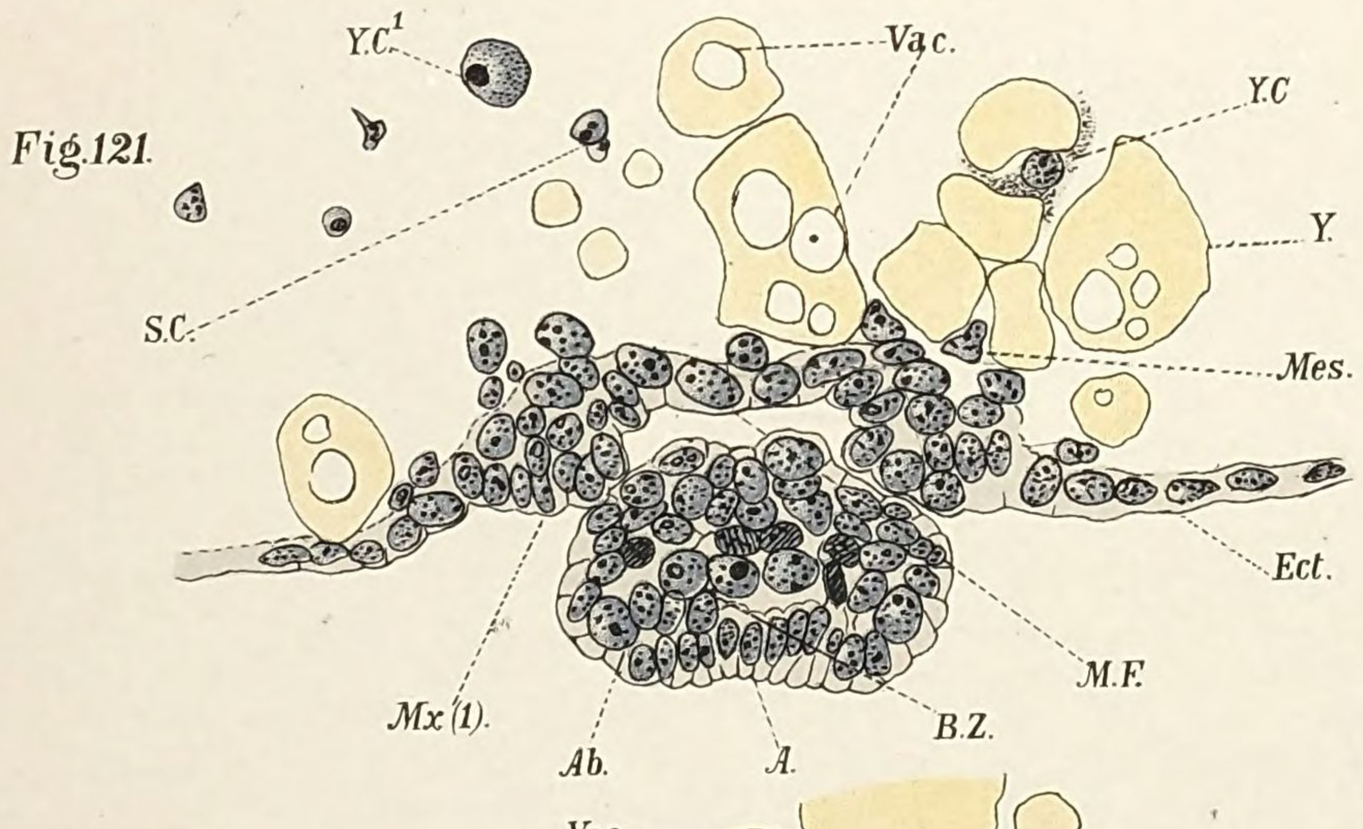
FIGS. 119–122. Serial transverse sections of the egg-nauplius, continued from Pl. XLI. In Fig. 120 a transverse row of cells with large clear nuclei is seen. This is probably a series of budding ectoblasts and mesoblasts, already referred to. Wandering cells appear to be settling down upon all parts of the embryo. In the thoracico-abdominal fold (Fig. 122, *mu.*) the abdominal muscles are already undergoing differentiation out of the mesoblast of the ventral plate. ×295.

REFERENCE LETTERS.

A., anal invagination.
A. (*II*), antennal bud.
Ab., abdomen.
A. Y. S., yolk undergoing change.
B. Z., budding zone.
Ect., ectoderm.
Hg., intestine.
Md., mandible.
Md. G., mandibular ganglion.
Mes., mesoderm.
M. F., median groove.
Mu., muscle cells.
Mx. (*I*), first maxillary bud.
s.[1], products of cell degeneration.
S. C., degenerating cells.
Y., yolk.
Y. C., *Y. C.*[1], wandering cells.
Vac., vacuole.







F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS SAULCYI.

PLATE XLIII.

(Stage VI.)

FIGS. 123, 124. Completion of series of transverse sections of egg-nauplius. Cells marked *Mes.* probably represent endoderm in Fig. 124. The heart is being formed at about this time out of mesoblast cells at *H*, Fig. XLIII, and the endoderm forms a plate between it and the central yolk (V, Fig. 133). ×295.

FIG. 125. Median longitudinal section of same stage. Compare with Fig. 106. The thoracico-abdominal fold is now distinctly directed forward, and is overgrowing the sternal area between it and the mouth. The stomodæum is a bent tube. ×295.

FIG. 126. Transverse section, cutting proctodæum. From an embryo of about the same age as that represented in Fig. 106. ×295.

FIG. 127. Transverse section of embryo and entire egg on level with anus, showing wandering cells (*Y. C.*, *Y. C.*$^{1-2}$). ×74.

REFERENCE LETTERS.

A., anal invagination.
Ab., abdomen.
A. Y. S., altered food yolk.
Ch., eggshell.
Ect., *Ep.*, ectoderm.
Gl., ganglionic rudiment.
H., rudiment of heart.
Hg., intestine.
Lb., labrum.
M b., embryonic molt.
Mes., mesoderm.
Mo., mouth.
Pd., region of proctodæal invagination.
s., *s*^{1}., products of cell degeneration.
S. C., wandering cells, probably in early stages of degeneration.
S. O. G., rudiment of brain.
St. A., sternal area.
Std., stomodæum.
Y., yolk.
Y. C., *Y. C.*$^{1-2}$, wandering cells.
Y. S., yolk spherules.
Vac., vacuole.

Fig. 123.

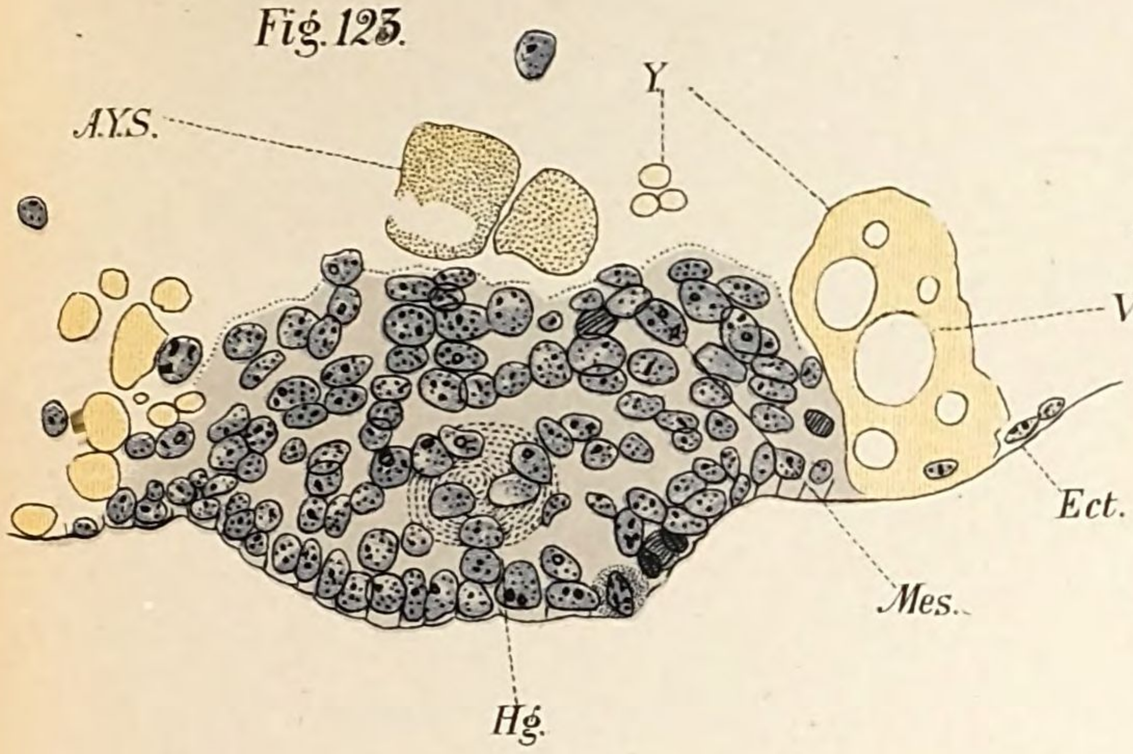


Fig. 124.

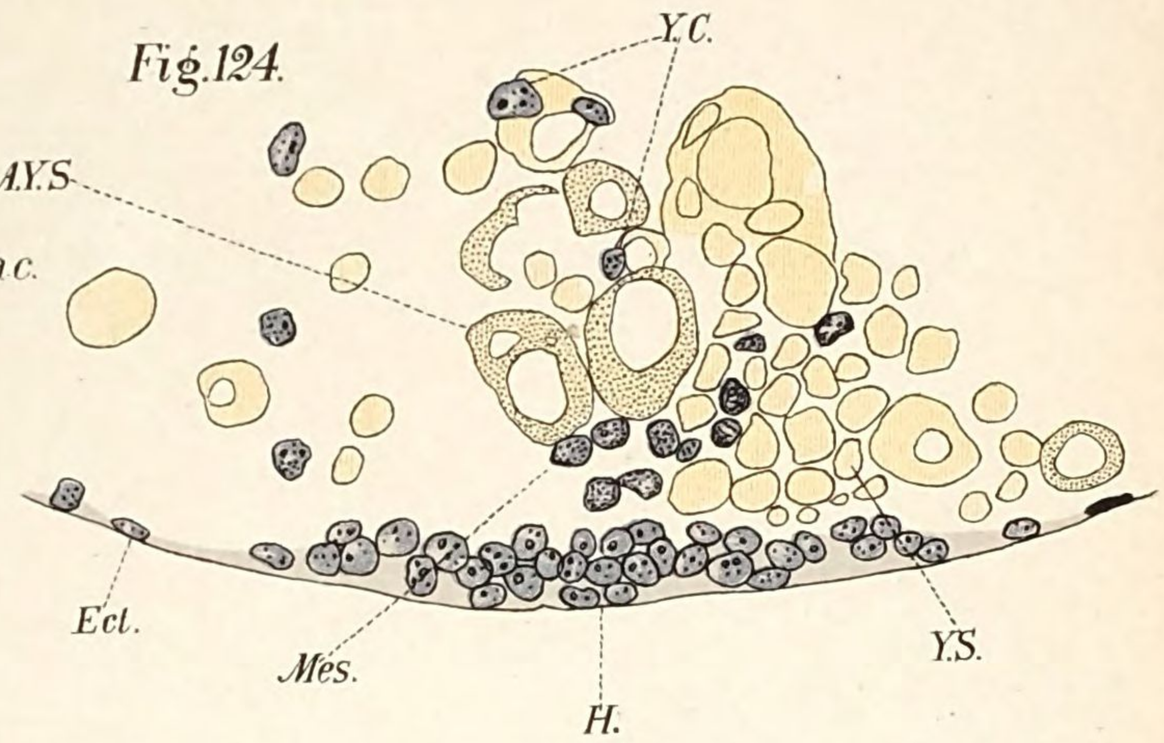


Fig. 125.

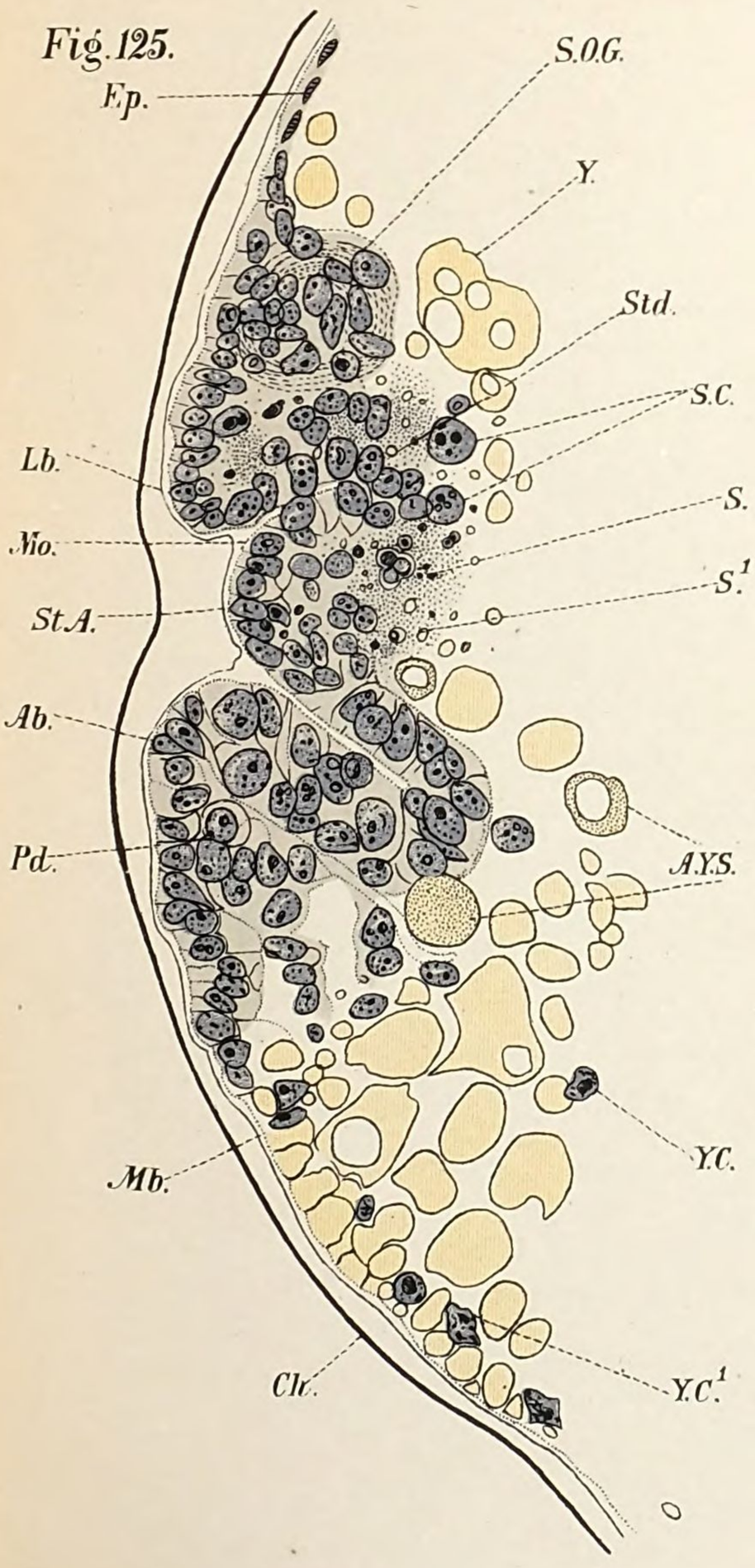


Fig. 126.

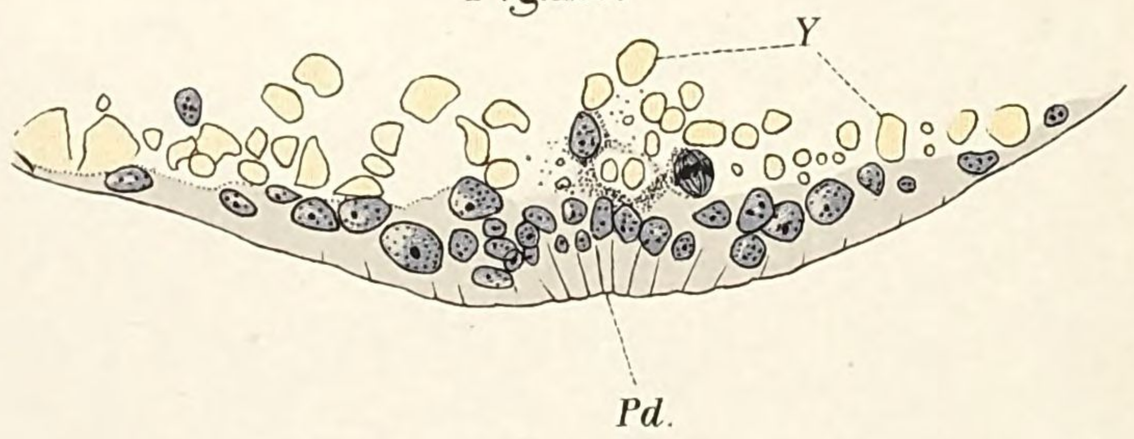
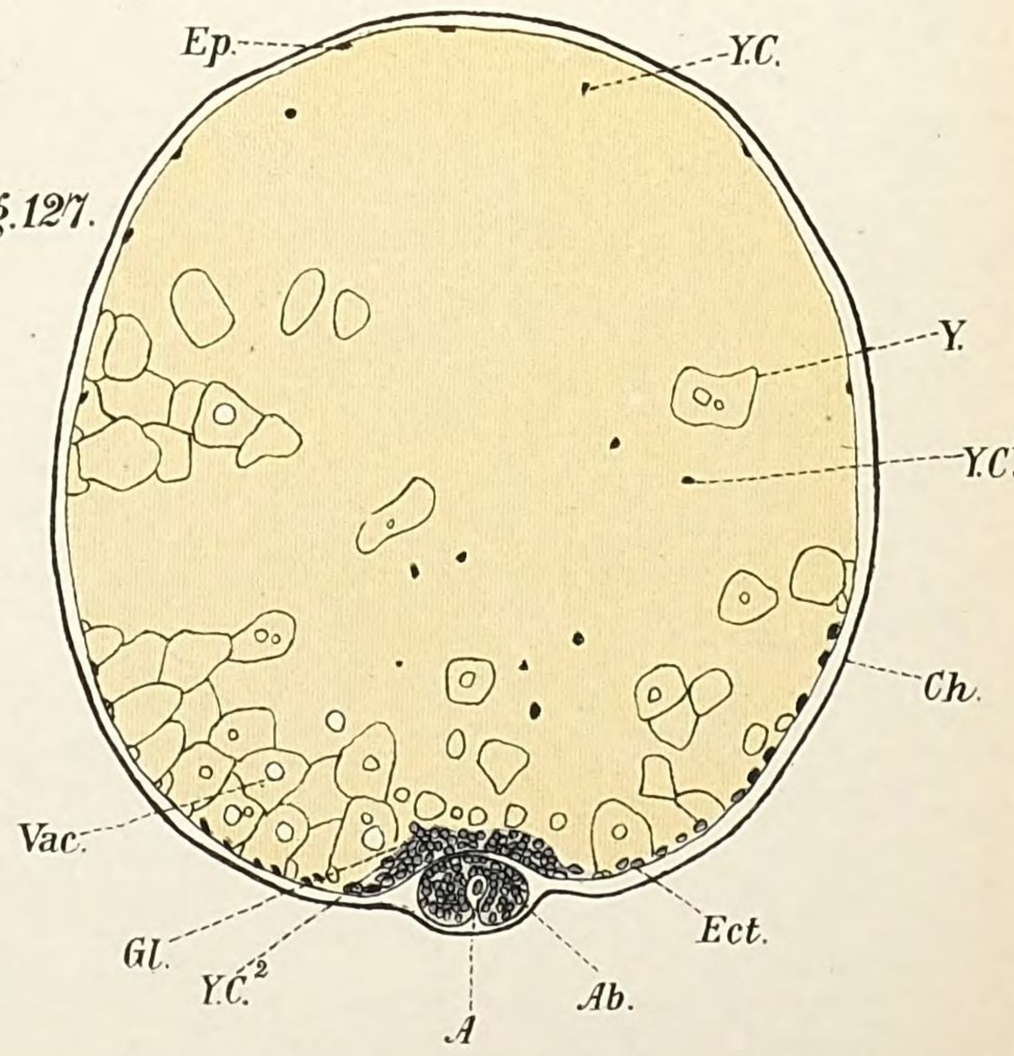


Fig. 127.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS SAULCYI

Plate XLIV.

(Stage VII.)

Fig. 128. Transverse section through embryo, in the region of the first maxilla. Nervous system not yet differentiated from the skin. ×234.

Fig. 129. Lateral longitudinal section through optic lobe and extremities of antennæ. The differentiation between the retinal and ganglionic parts of the eye is very clear. Mesoblastic cells, representing rudimentary muscles, are seen attached to the body wall. ×234.

Fig. 130. Surface view of embryo of this stage, with buds of four post-mandibular appendages present. The antennæ are covered with a hairy exuvium, which was probably stripped off from the antennules in this preparation. The mouth is concealed by the labrum, which nearly meets the thoracico-abdominal fold. The anus is situated nearly at the extremity of the latter, which is slightly emarginated. ×137.

Fig. 131. Median longitudinal section in the series from which Fig. 129 was taken. ×234.

Figs. 132–135. Serial transverse sections through embryo in similar stage. The germinal layers, definitely established in the egg-nauplius stage, are clearly differentiated at this period. An incomplete layer of elongated cells (probably mesoblastic in origin, coming from wandering yolk cells), *Mes.*, Figs. 131, 132, is seen between the yolk and the neural thickening, from which the nervous system is in process of development. In Fig. 134 rudimentary muscles suspend the stomodæum to the body wall, and in Figs. 133 and 135 the three germinal layers can be clearly seen. The heart is represented by the space filled with mesoblast and serum, between the entoblastic lamella and the ectoblast. ×234.

REFERENCE LETTERS.

A. I, first antenna.
A. II, second antenna.
Ab., thoracico-abdominal fold.
A. Y. S., alteration products of the yolk.
Ect., ectoderm.
End., endoderm.
G. L., rudiment of optic ganglion.
Gl. A. II, antennular ganglion.
Lb., labrum.
Mes., mesoderm.
Mo., mouth.
Mu., rudimentary muscles.
Mx. I, first maxillary bud.
O. E., retinal portion of optic lobe.
S. O. G., brain.
Std., stomodæum.

Fig. 128.

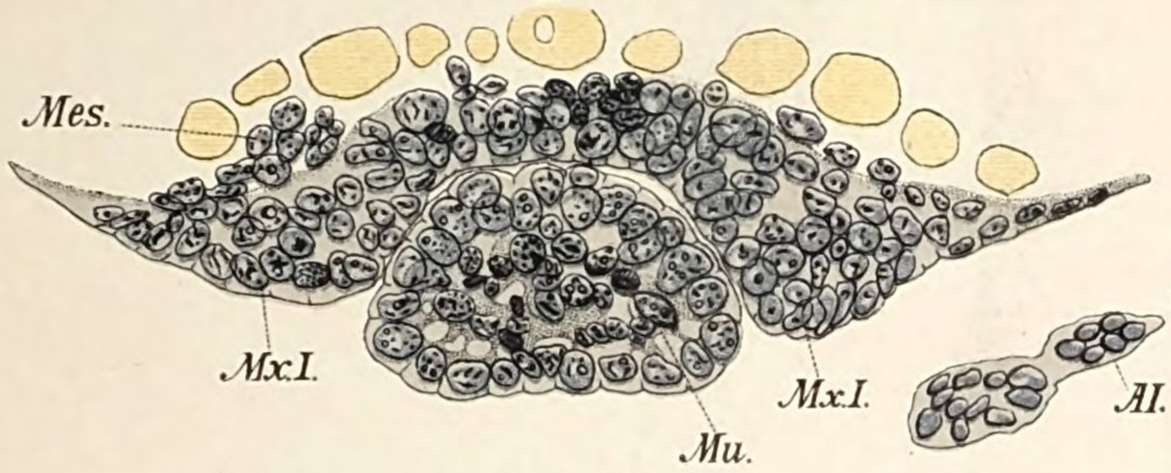


Fig. 131.

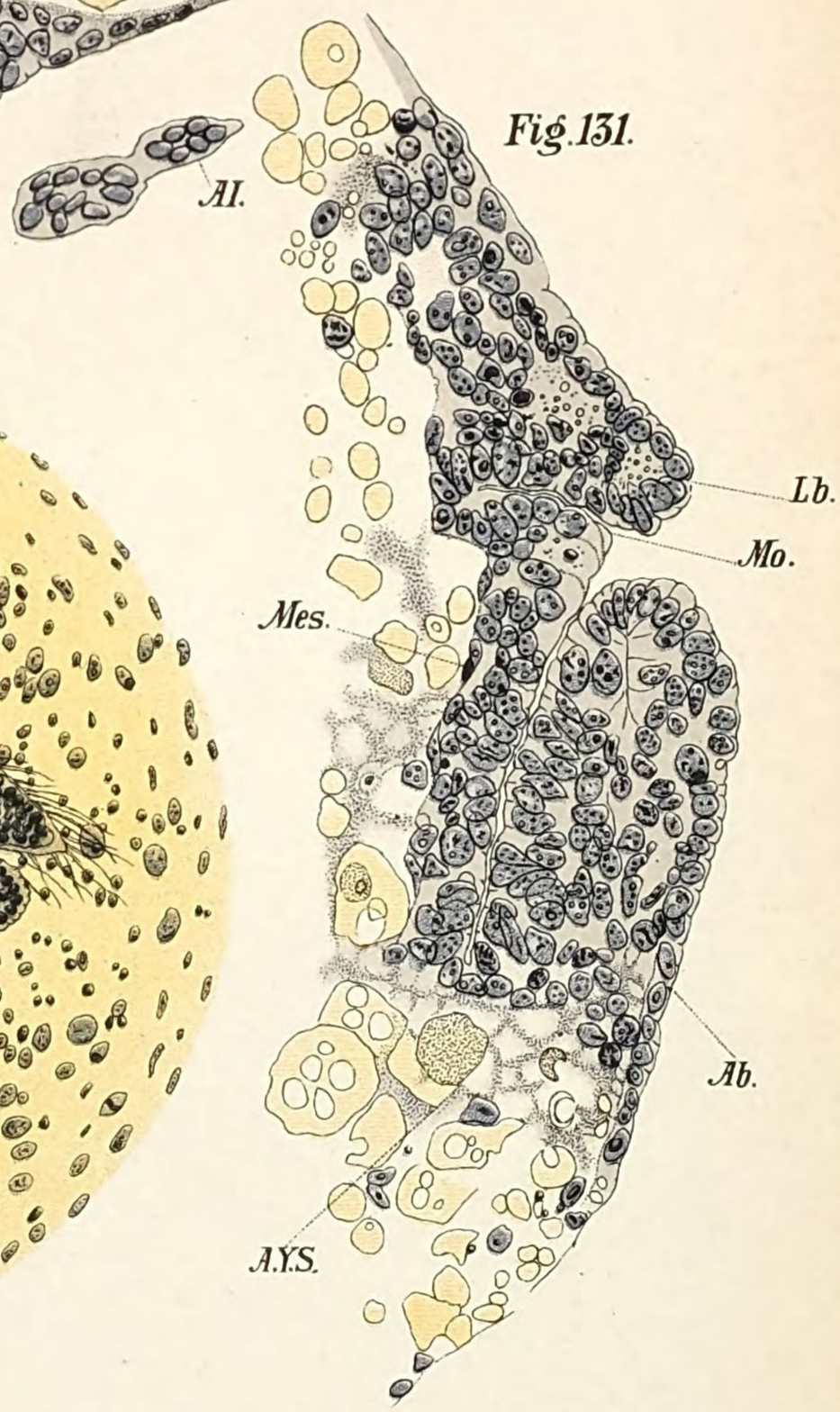


Fig. 130.

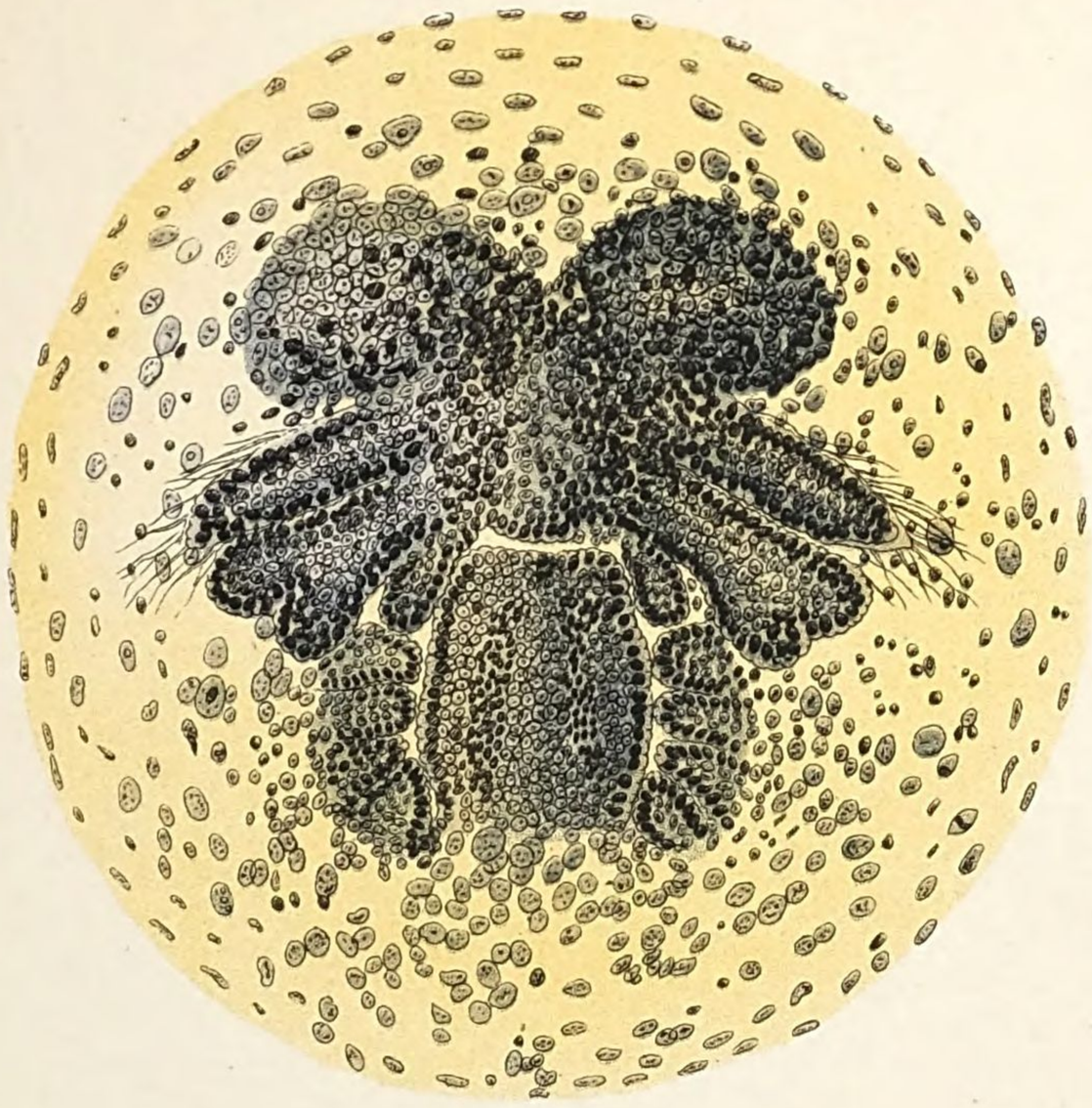


Fig. 129.

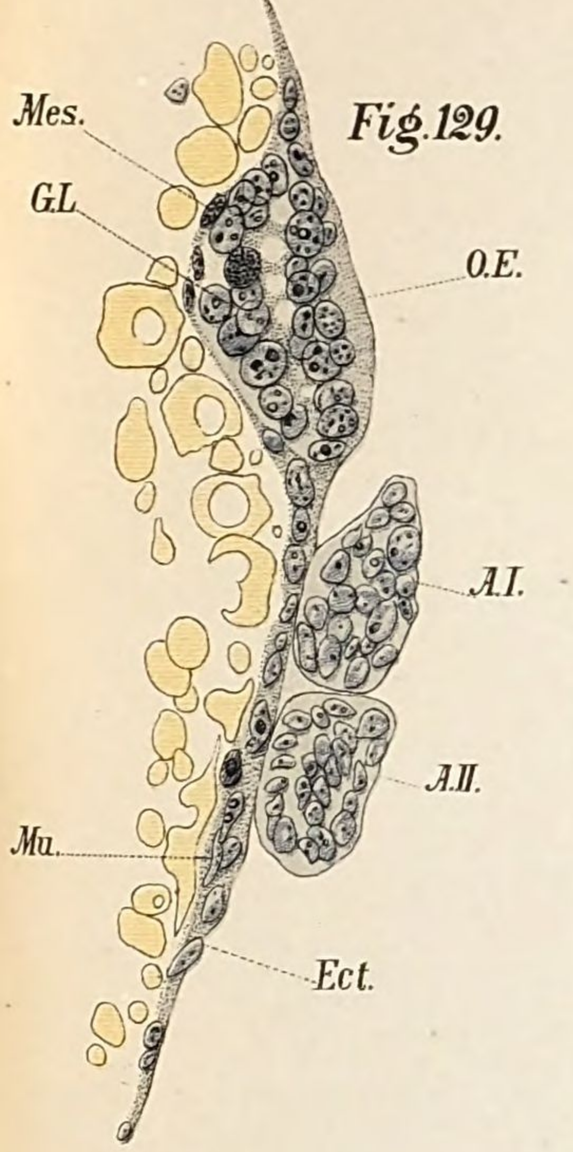


Fig. 132.

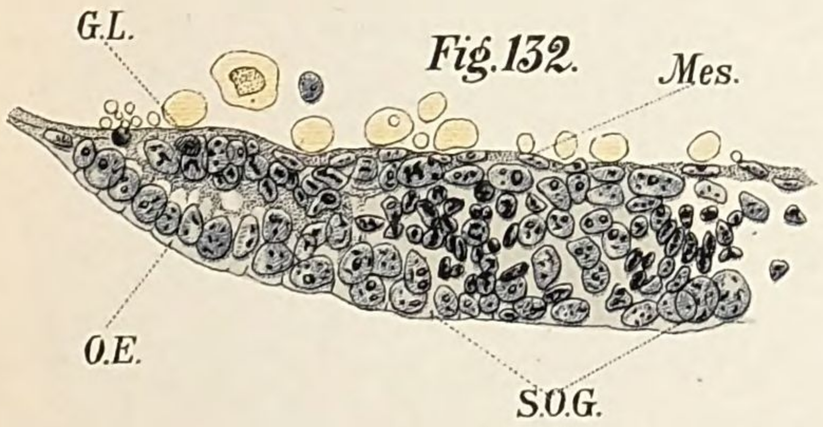


Fig. 133.

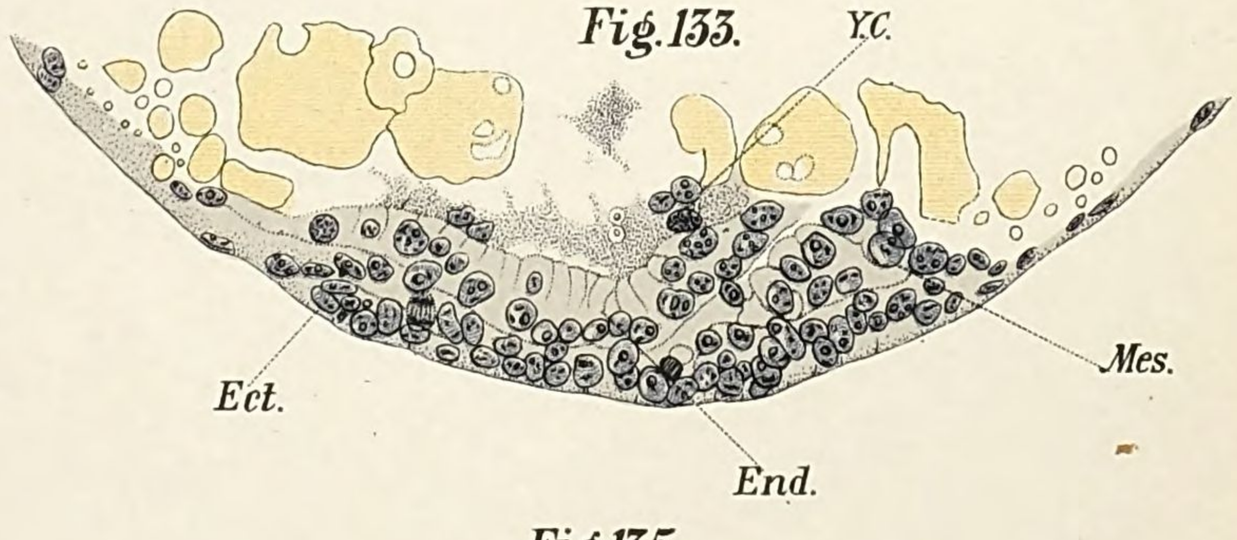


Fig. 134.

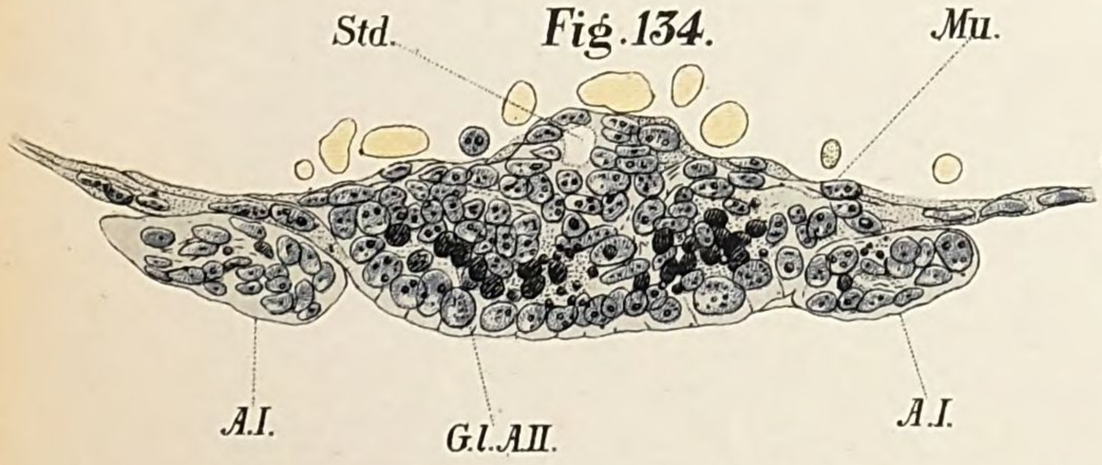
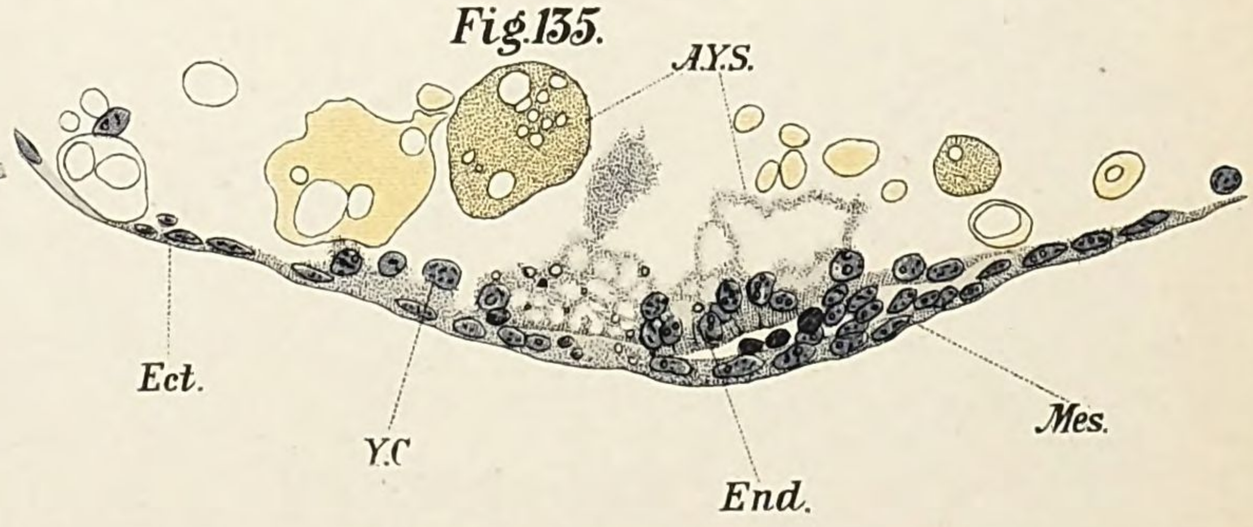


Fig. 135.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

PLATE XLV.

(Stage VIII.)

FIG. 136. Lateral longitudinal section of embryo in stage intermediate between VII and VIII, represented in surface view in Fig. 110. To this phase also belong Figs. 137, 144, and 145. Fig. 136 is to be compared with the slightly older embryo in Fig. 129. Blood cells (*B. C.*) and other wandering cells are here seen settling down upon the body wall. A wandering cell is also seen nearly in contact with the optic ganglion. ×241.

FIG. 137. Transverse section of embryo in same phase, just behind the level of the first antennæ, showing the relations of the wandering cells at this period to the embryo and egg. ×61.

FIGS. 138, 139. Serial longitudinal sections through embryo in Stage VIII. Fig. 138 should be compared with Figs. 136 and 129. All the ganglia of the nervous system, at least as far back as the eighteenth segment, are marked at the surface by deep constrictions. The ganglia of the nineteenth and twentieth segments are less distinct. The ganglia of the eleventh segment lie in the angle made by the thoracico-abdominal flexure. Wandering cells occur in the yolk, but are less abundant, and the products of cell degeneration, which enter into the general nutrition, have mostly disappeared. ×241.

FIGS. 140–143. Parts of sections taken at various points on the surface of the egg (series to which Figs. 136, 137, 144, 145, belong), remote from the embryo, to show the rôle of certain wandering cells which reach the surface and represent mesoblast. In Fig. 140 two cells (*ms.*, *ms.*[1]) are partially flattened against the surface, but here, as in Fig. 142, the wandering cell *ms.* is clearly distinguishable from the spindle-shaped ectoderm cell on the left. Compare Fig. 34. ×241.

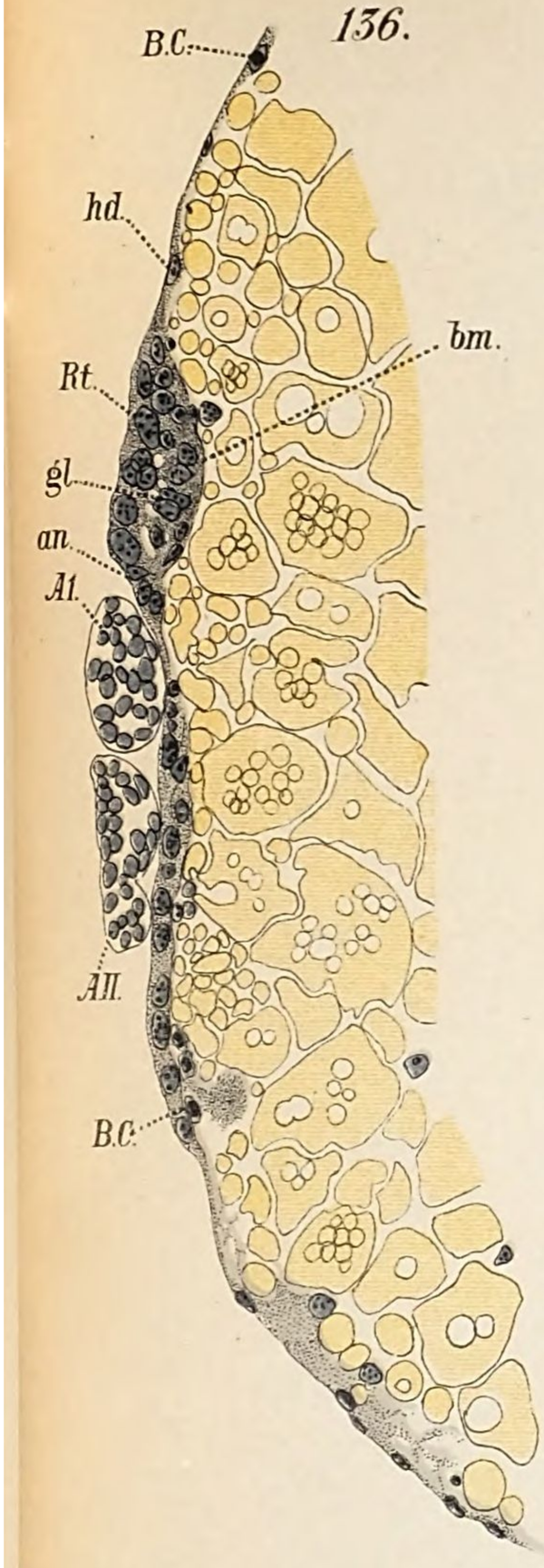
FIGS. 144–145. Serial longitudinal sections through the embryo and entire egg to show the distribution of the wandering cells. Certain wandering cells not yet flush with the surface, enter into an organ—the dorsal plate (*Dp.*)—which is characteristic of a later stage (Fig. 153, *Dp.*). The strictly superficial cells of the dorsal plate are probably in all cases ectoblast, and some of the wandering cells degenerate before they reach the surface ectoblast.

There seems to be a general dispersal of wandering cells from the vicinity of the thoracico-abdominal fold. The wandering cells which appear in this part were taken from four consecutive sections, including that represented in the drawing. ×61.

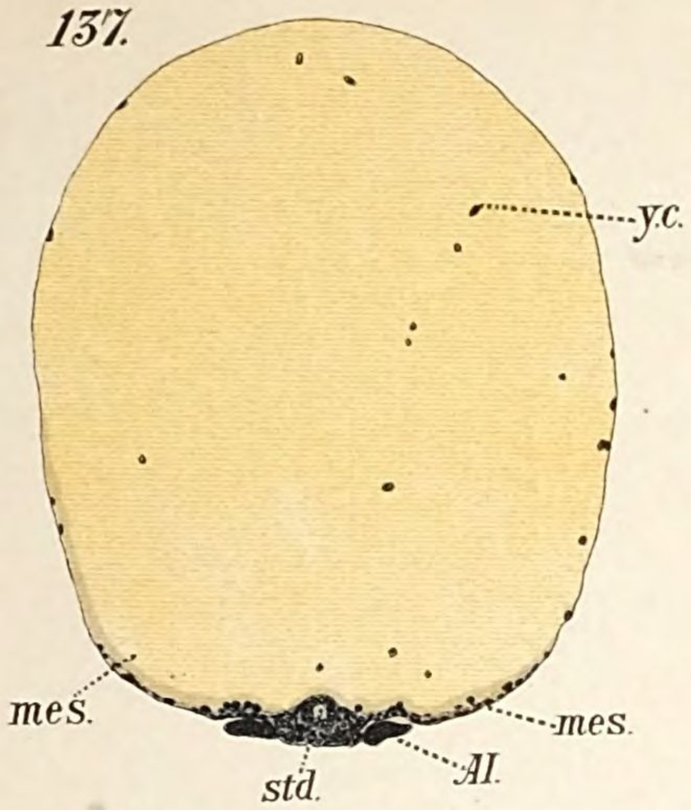
REFERENCE LETTERS.

A. I, first antenna.
A. II, second antenna.
an., lower margin of optic lobe.
A. s. a., superior abdominal artery.
B. C., blood corpuscle.
b. m., basement membrane.
ch., eggshell.
Dp., dorsal plate.
End., endoderm.
G. IV–XVIII, segmental ganglia.
Gl., gangliogen.
H., heart.
hd., hypodermis.
Hg., hindgut.
mes., mesoblast.
mo., mouth.
ms., *ms.*[1], wandering cells at surface.
O. L., optic lobe.
Rt., retinogen.
Std., stomodæum.
Th. ab., thoracic-abdominal fold.
y. c., wandering cells.

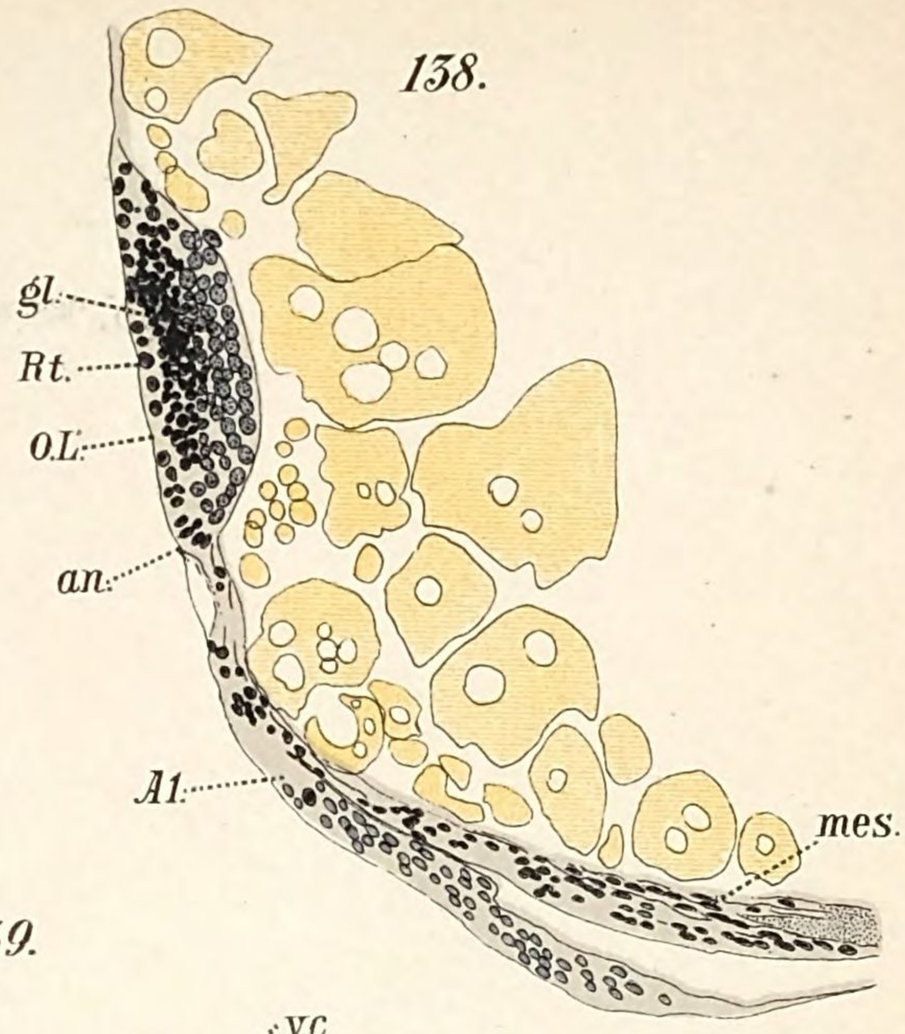
136.



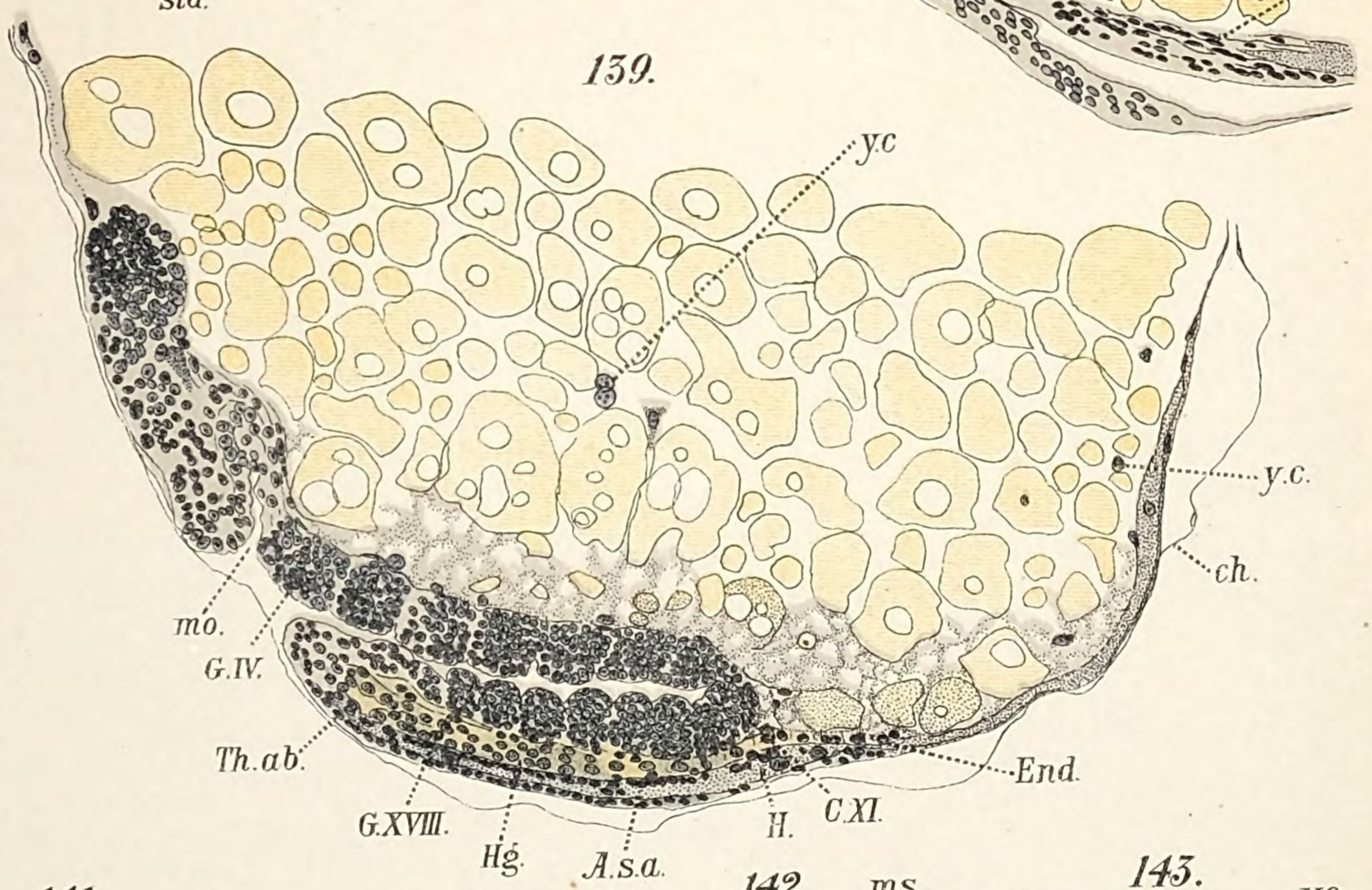
137.



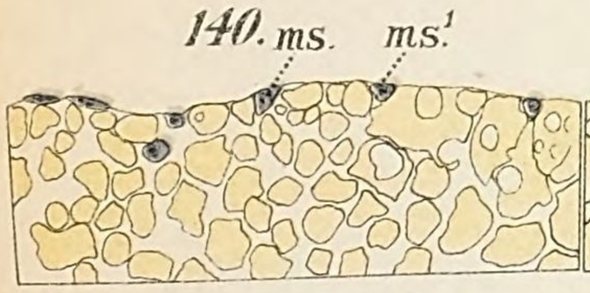
138.



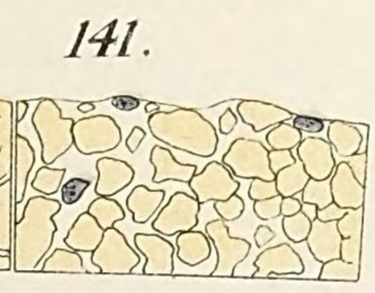
139.



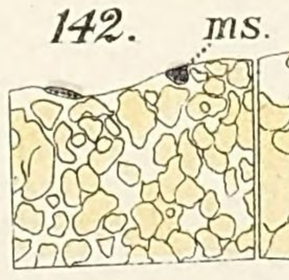
140.



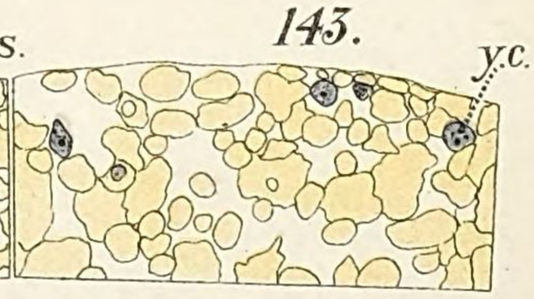
141.



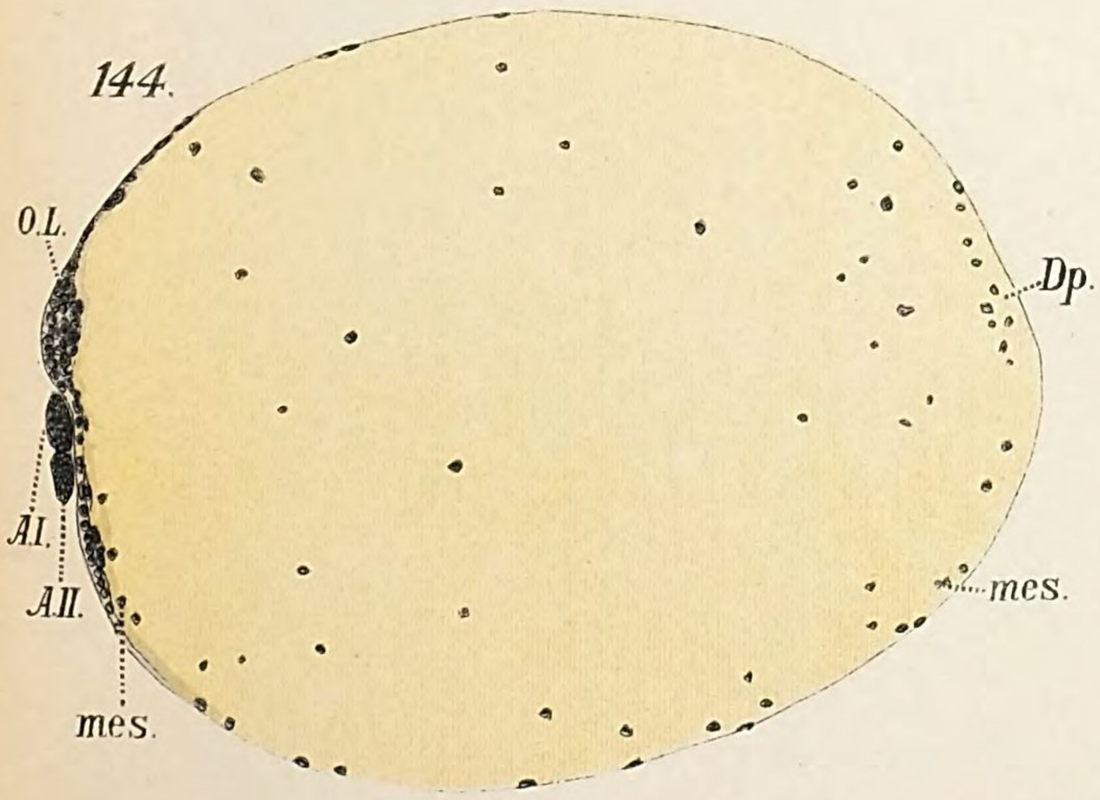
142.



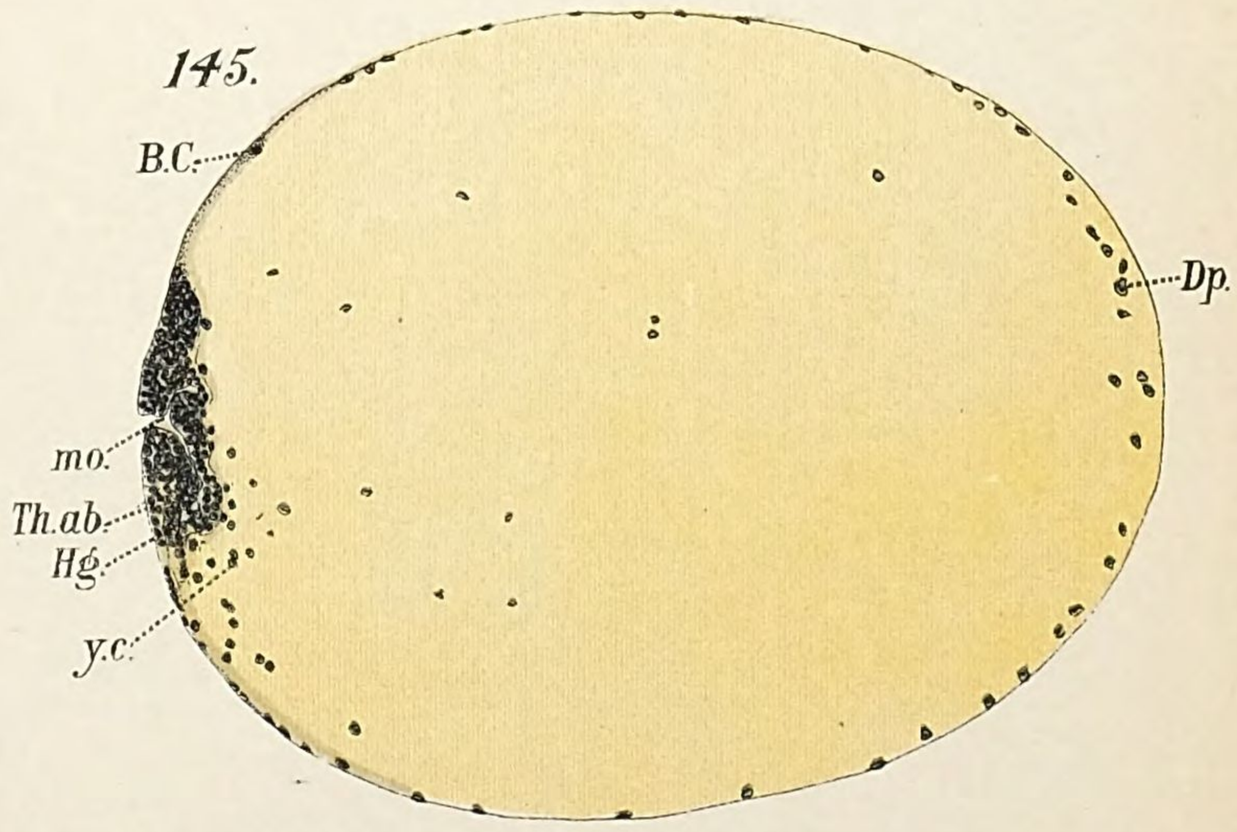
143.



144.



145.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

PLATE XLVI.

(Stage IX.)

FIGS. 146–151. Serial transverse sections, through the embryo of *A. saulcyi*, at the time when pigment is first deposited in the eye. In Fig. 146 the developmental history of the retinal layer is well shown. ×230.

FIG. 152. Nearly median longitudinal section of embryo in similar stage. ×58.

FIG. 153. Sagittal section of similar embryo, showing degenerating elements in yolk below dorsal plate. ×58.

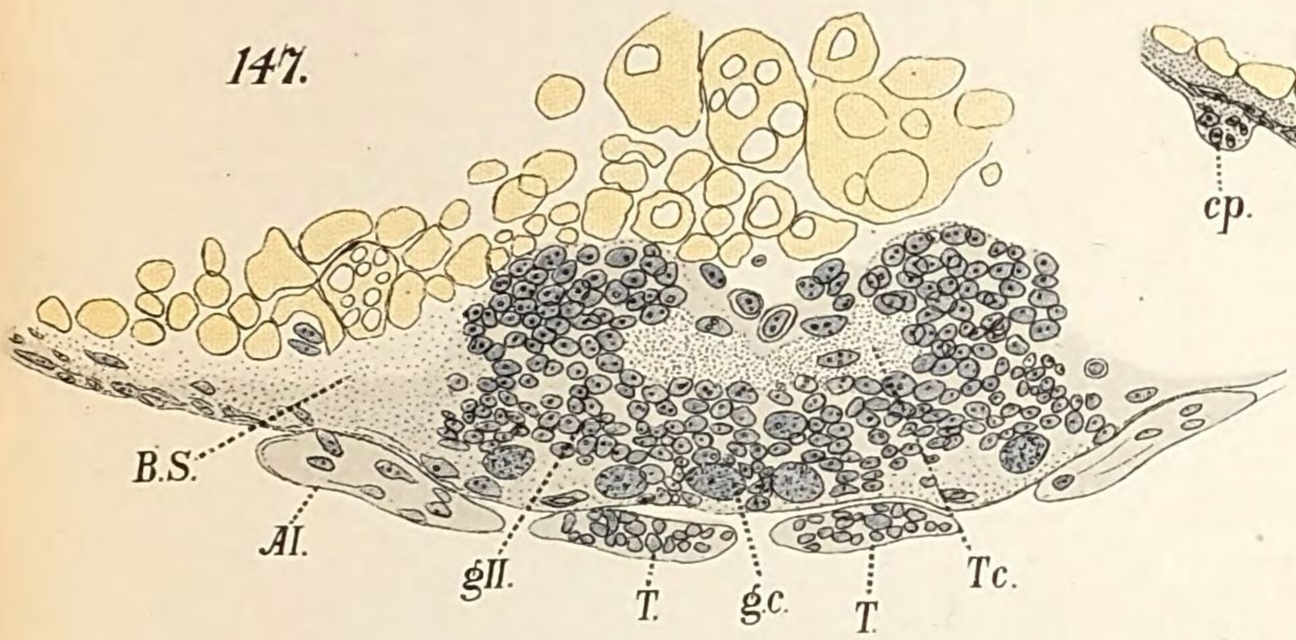
REFERENCE LETTERS.

A. I, first antenna.
A. II, second antenna.
Ab., abdomen.
B. C., blood corpuscle.
B. S., blood space.
cp., carapace.
Deg., degenerating cells.
Dp., dorsal plate.
End., endoderm.
fg., foregut.
fs., fiber mass of nervous system.
g. II–III, brain.
g. c., ganglion cell.
g. m. a., anterior gastric muscle.
H., heart.
hd., hypodermis.
Hg., hindgut.
Lb., labrum.
Md., mandible.
Mes., mesoblast.
Mu. f., flexor muscle.
ocm., œsophageal commissure.
o. g., optic ganglion.
O. L., optic lobe.
pk., punct substanz.
pr., perineurium.
Rt., retinogen.
S. O. G., supra-œsophageal ganglion.
T., telson.
Tc., transverse commissure.
Th., thorax.
Vac., vacuole.
y., yolk.
Y. C., wandering cells.

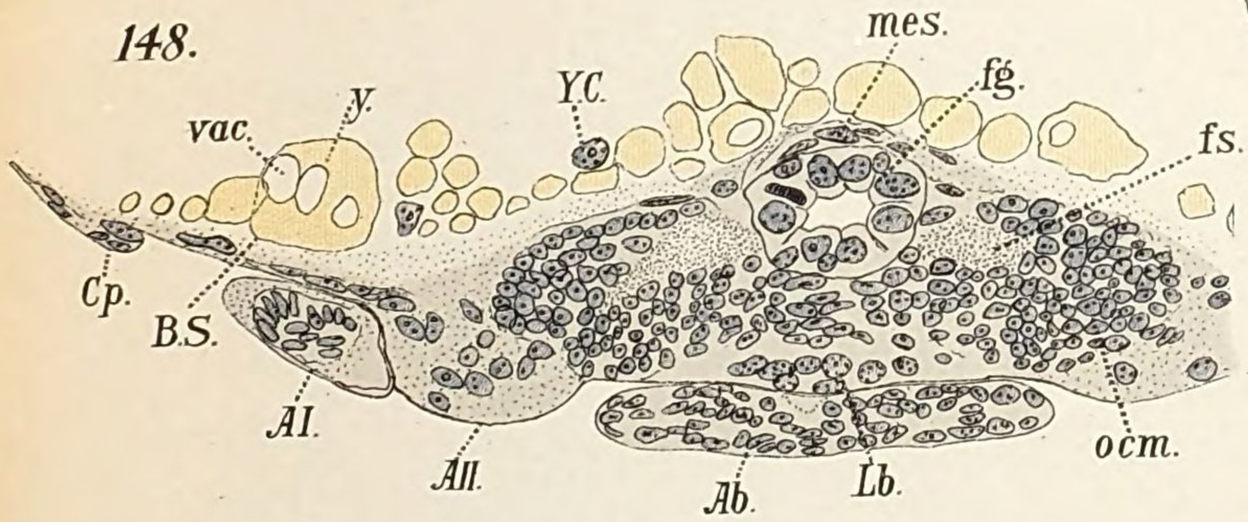
146.



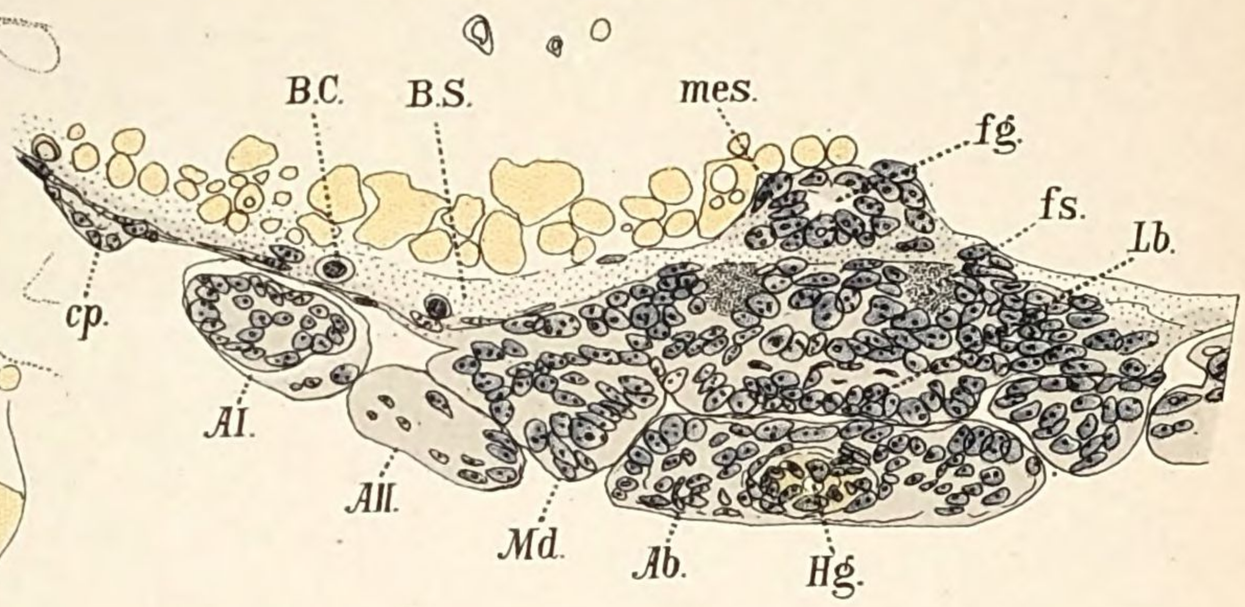
147.



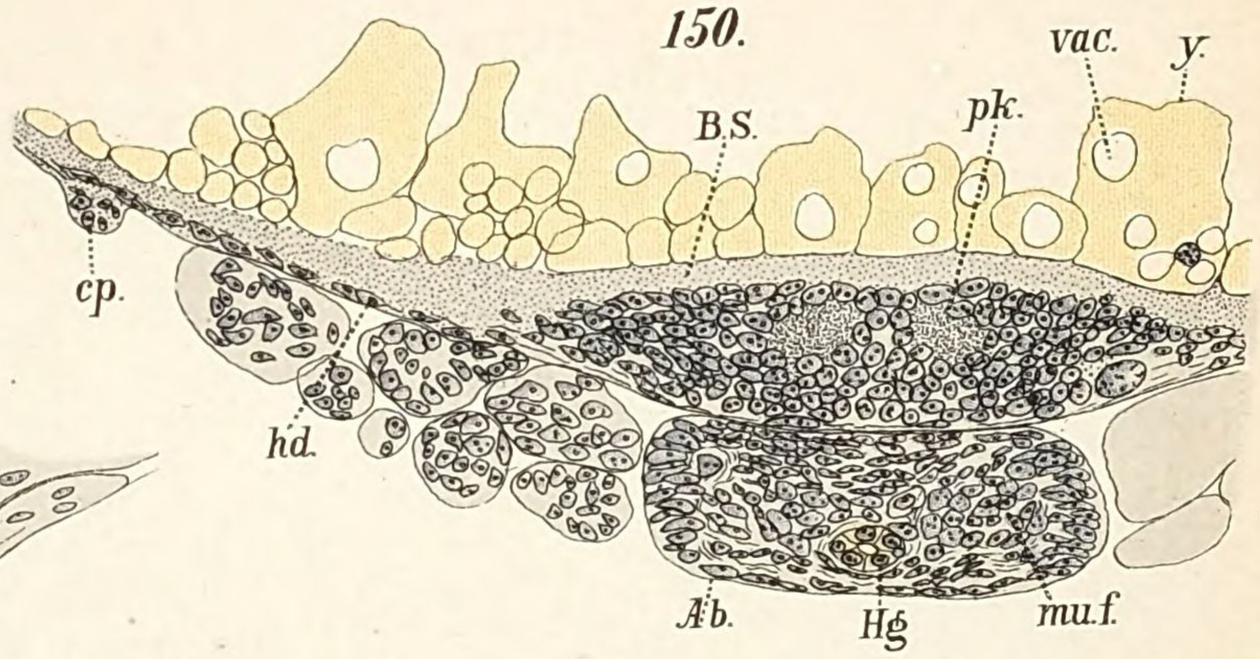
148.



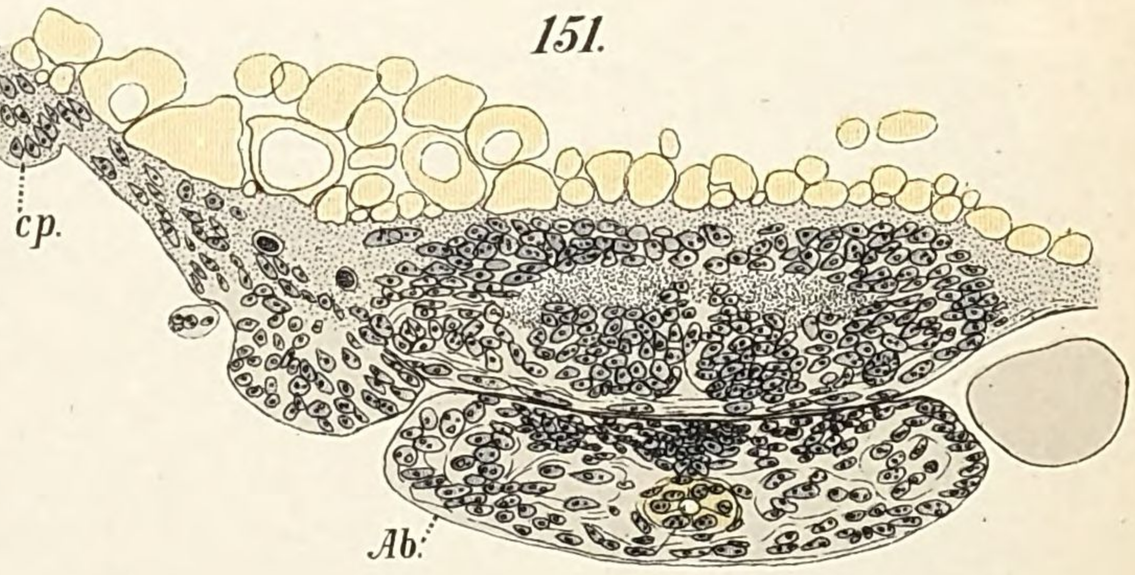
149.



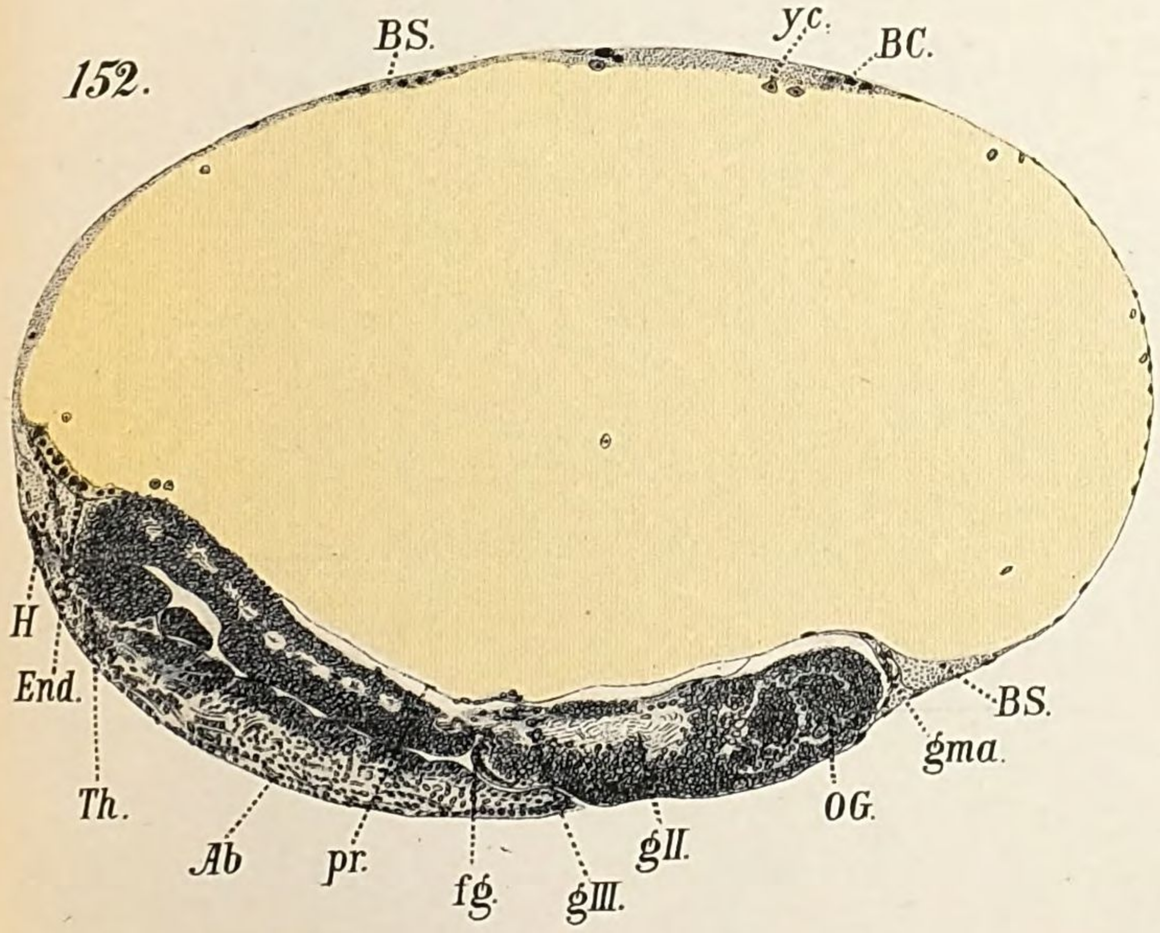
150.



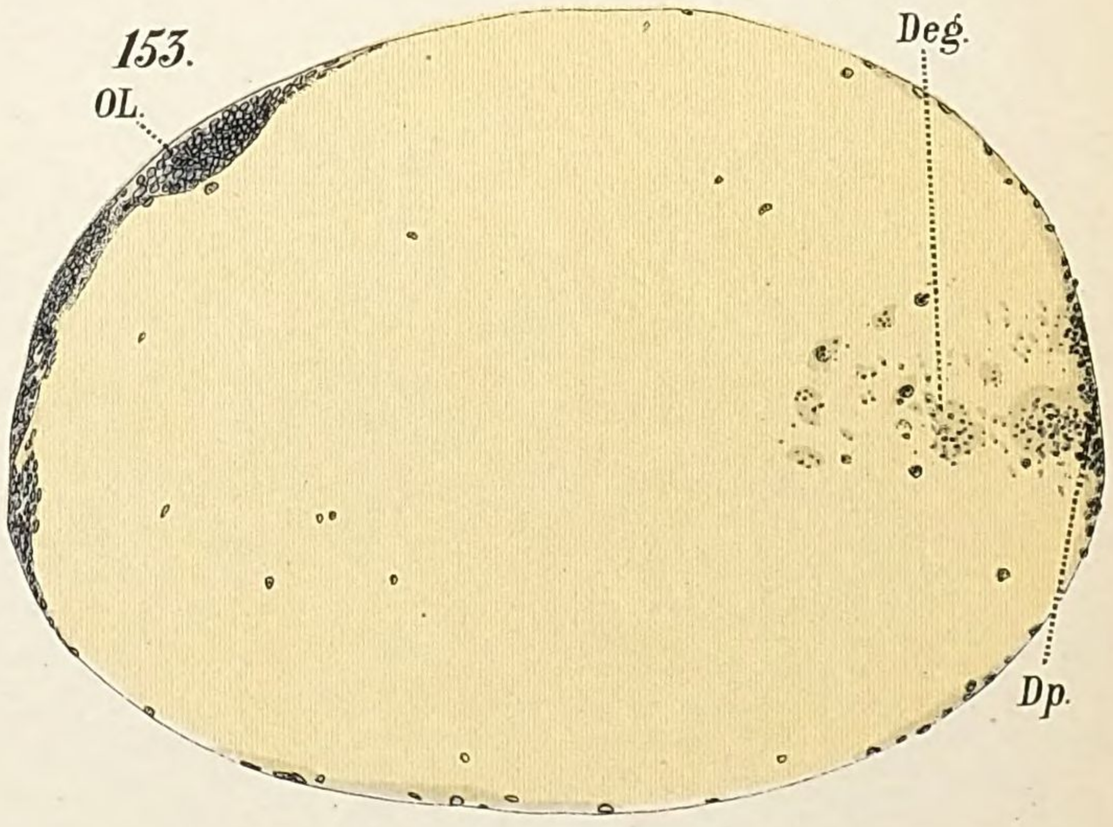
151.



152.



153.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

PLATE XLVII.

(Stage IX.)

FIGS. 154, 155. Transverse sections through entire embryo of *Alpheus saulcyi*. In Fig. 154 a yolk nest is cut. Blood spaces occur near the surface of the egg. ×61.

FIG. 156. Cell nest, containing degeneration products. Its position in the yolk is shown in Fig. 154. ×245.

FIG. 157. Part of median longitudinal section through the thoracic-abdominal flexure. The growing endodermal epithelium and its fusion with the lining of the intestine are particularly well shown. Wandering cells appear to be uniting with the endoderm. ×245.

FIG. 158. Sketch of egg embryo, *Alpheus saulcyi*, of same phase as that represented by Fig. 157. ×61.

FIG. 159. Horizontal section through brain and eyestalks of a slightly older embryo. ×61.

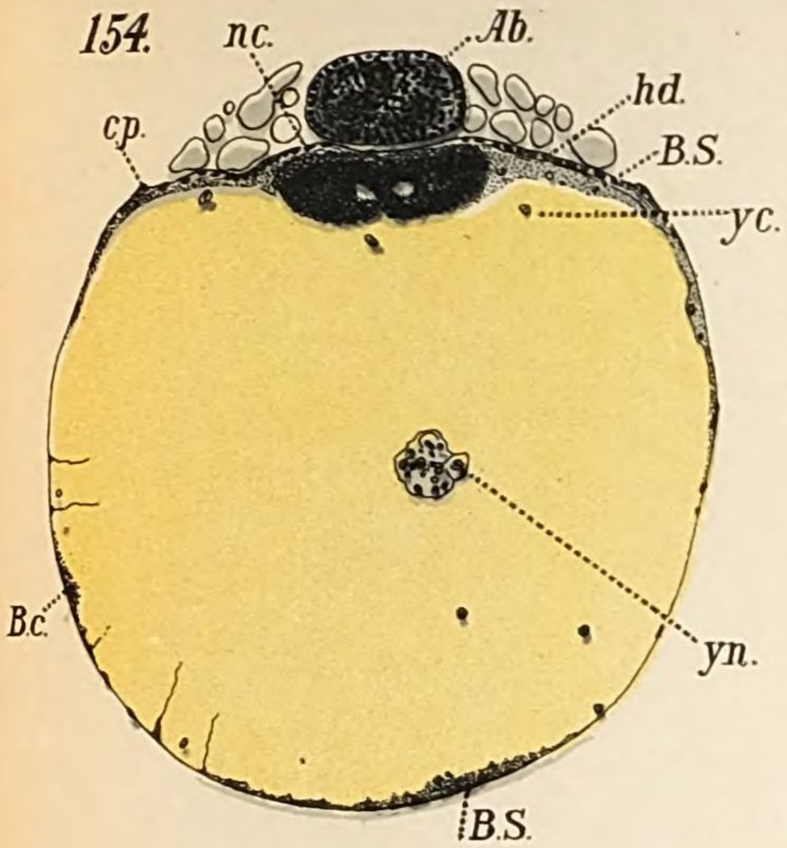
FIG. 160. Part of transverse section of similar embryo on level with the mandibles. ×245.

FIG. 161. Superficial part of section of egg, showing surface cells, blood corpuscles, and a wandering cell on the edge of the blood space. ×245.

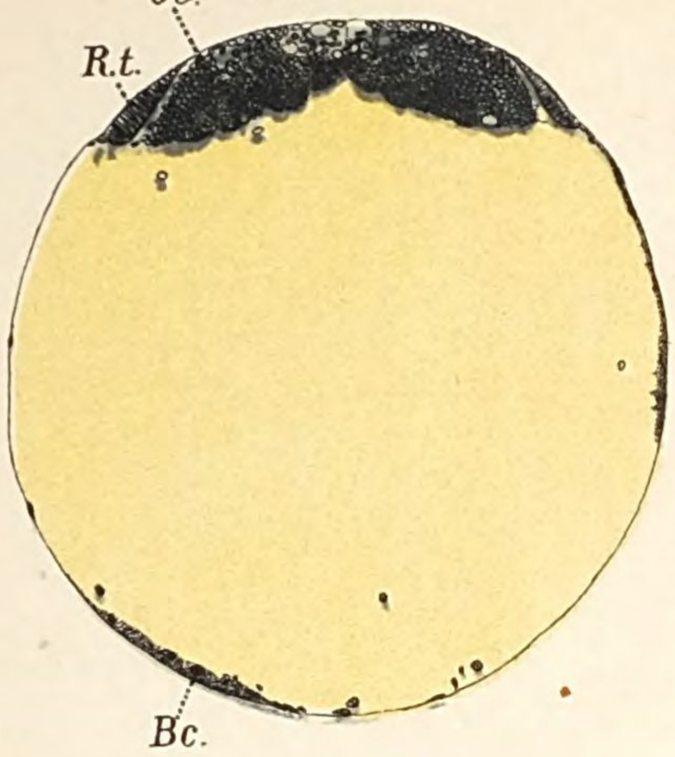
REFERENCE LETTERS.

A. I, first antenna.
A. II, second antenna.
Ab., abdomen.
aor., aorta.
a. y. S., granulated yolk products.
B. C., blood cell.
B. S., blood space.
Ch., eggshell.
cp., carapace.
Deg., products of cell degeneration.
Ect., ectoderm.
End., endoderm.
fs., fiber-substance of nerve cord.
G. IV, ganglion of mandible.
gc., ganglion cell.
gf., fiber ball of second antenna.
H., heart.
hd., hypodermis.
hg., hindgut.
lf., lateral fiber-mass of brain.
Md., mandible.
Mes., mesoblast.
Mu., muscle cells.
Mu. f., flexor muscle.
Mts., metastoma.
n. c., neural cord.
O. G., optic ganglia.
of., optic enlargement.
p. c., pillars of carapace.
p. r., perineurium.
p. s., pericardial sinus.
Rt., retinogen.
Std., stomodæum.
vac., vacuole.
y. c., wandering cell.
y. n., yolk nest.

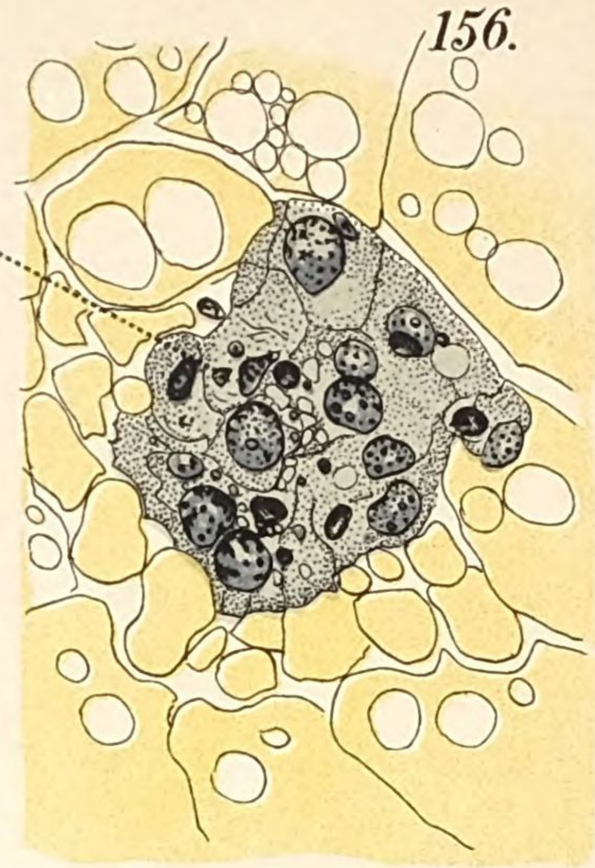
154.



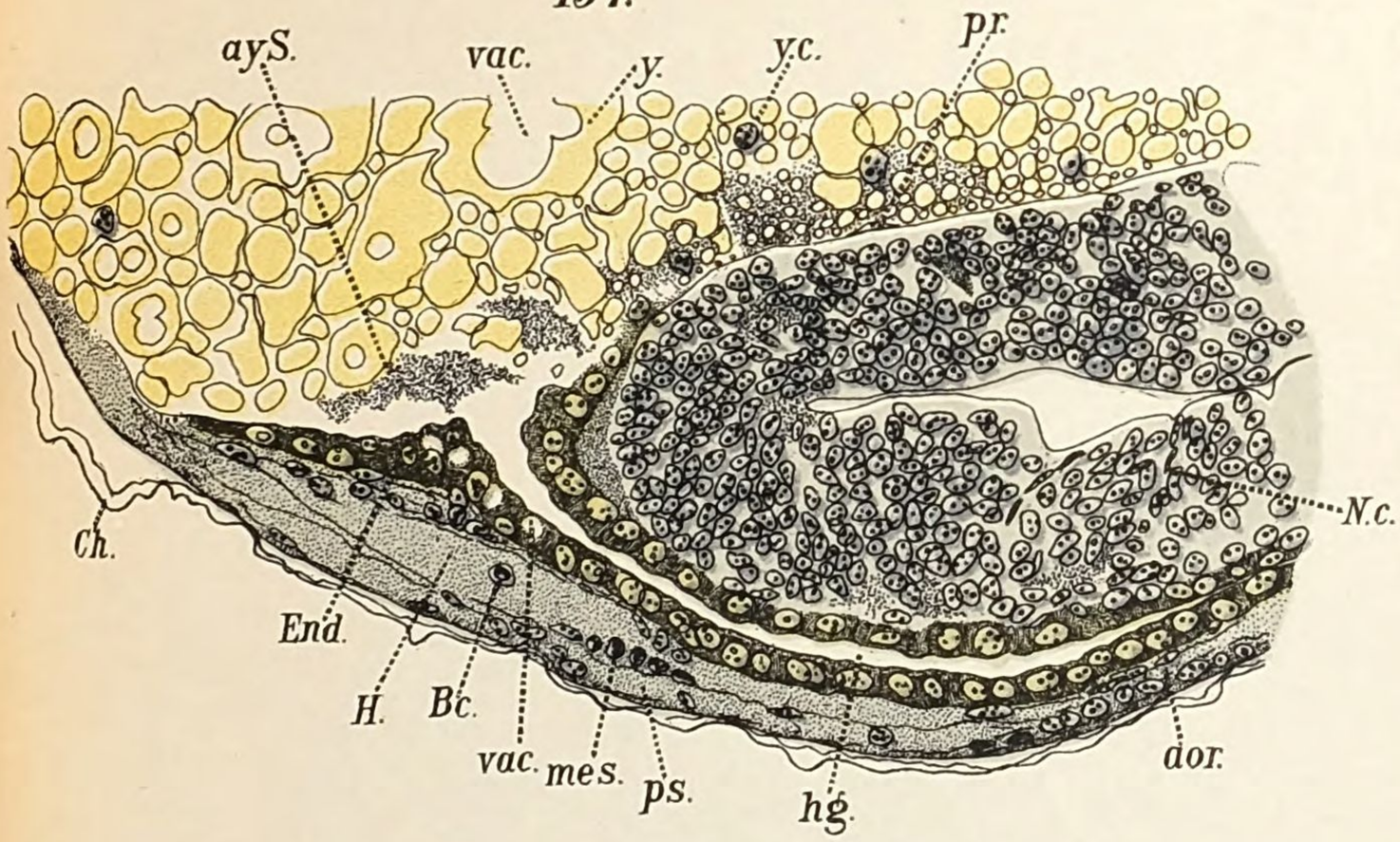
155.



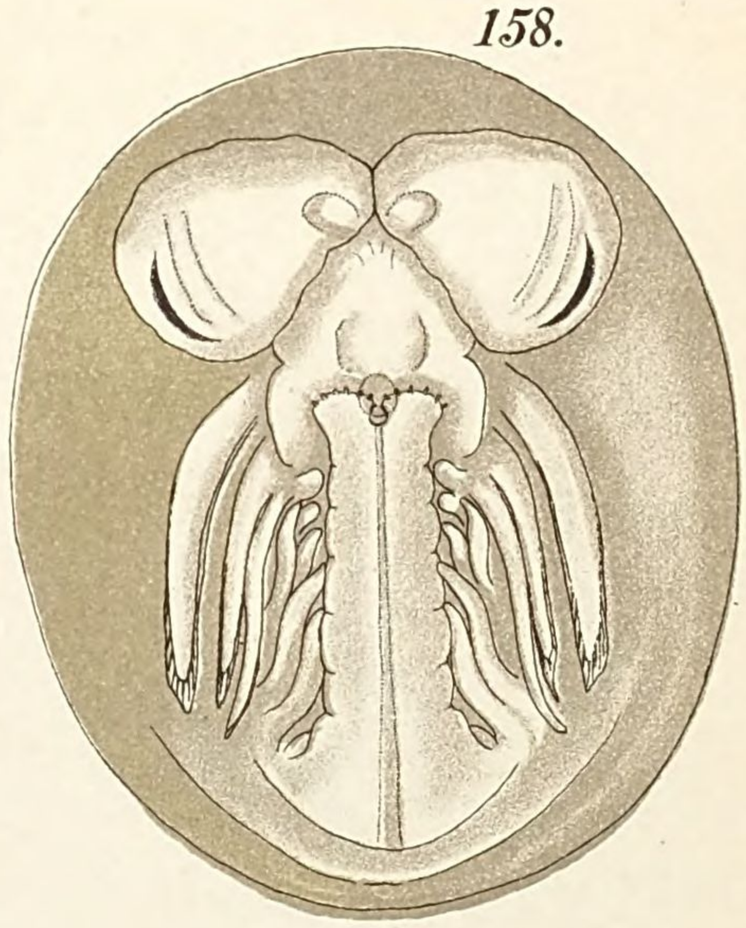
156.



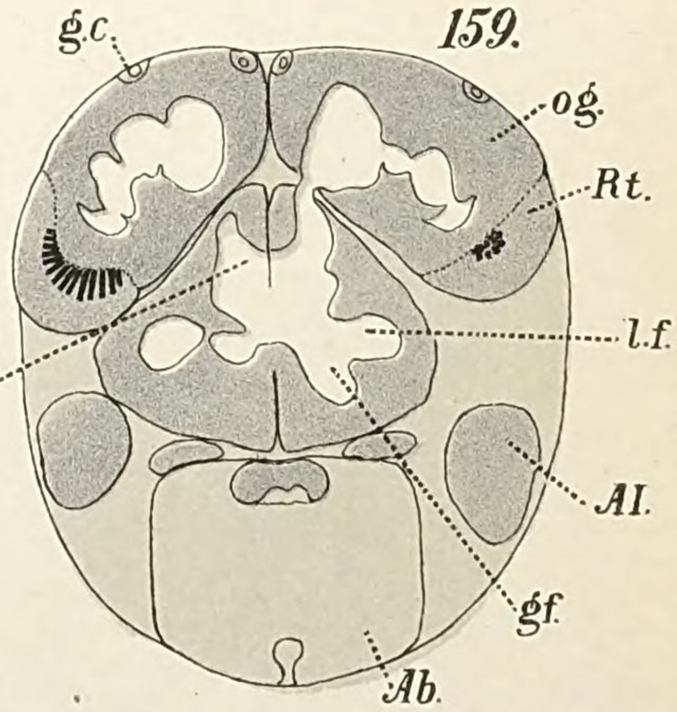
157.



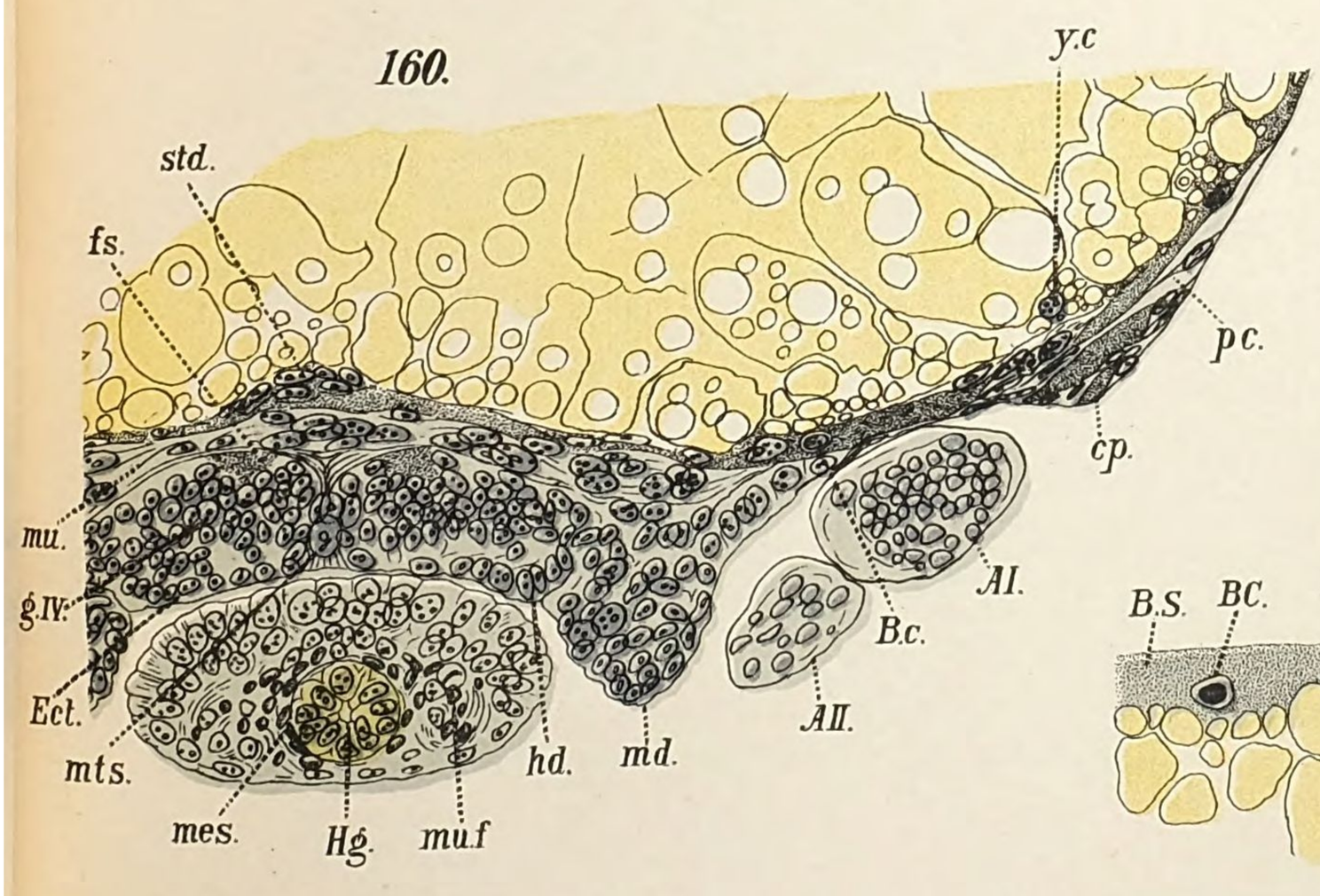
158.



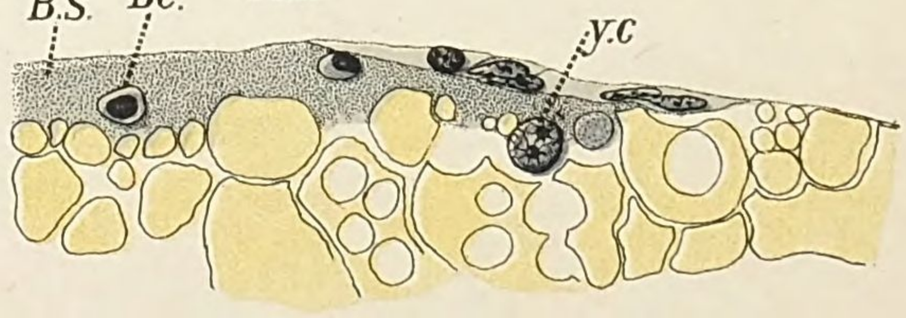
159.



160.



161.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS

Plate XLVIII.

(Stage X.)

Figs. 162–165. Parts of serial sections through the region of the heart and thoracic-abdominal fold to show the extension and relations of the endoderm. ×57.

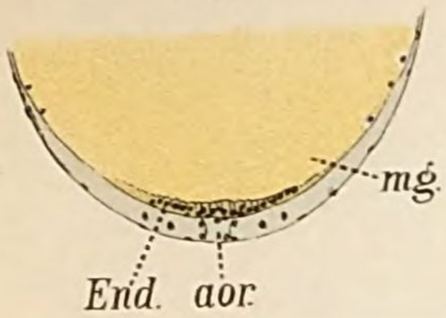
Figs. 166—167. Parts of serial transverse sections of the embryo of *Alpheus saulcyi*. ×125.

Fig. 168. Median longitudinal section through a slightly older embryo, showing the ventral endodermic fold (*f*), the foregut still screened from the yolk, and the nervous system separated from the skin. ×227.

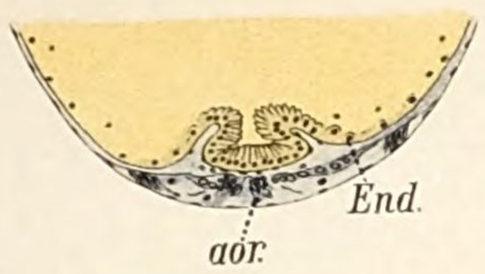
REFERENCE LETTERS.

Ab., abdomen.
Ab. g. I, first abdominal ganglion.
aor., aorta.
B. C., blood cell.
B. S., blood space.
cc., crystalline cone cells.
Deg., products of degeneration.
Ecp., proximal retinular cells.
End., endoderm.
f., ventral endodermic fold.
g. m. a., anterior gastric muscle.
H., heart.
Hg., hindgut.
imb., intercepting membrane.
mg., mesenteron.
mo., mouth.
mpgI, first maxillipedal ganglion.
Mu. E., extensor muscles.
Mu. f., flexor muscles.
O. G., optic ganglia.
p. s., pericardial sinus.
Rt., retinogen.
S. O. G., supra-œsophageal ganglion.
T., telson.
Th., thorax.
Th. g. I, ganglion of first ambulatory limb.
y. c., wandering cells.

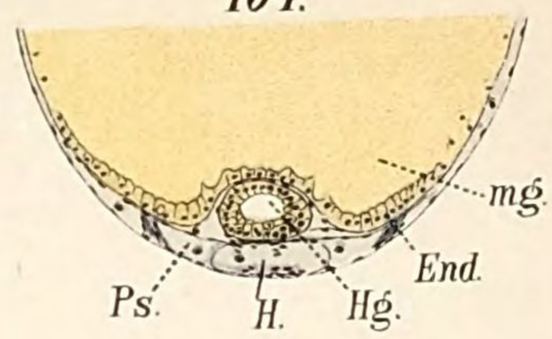
162.



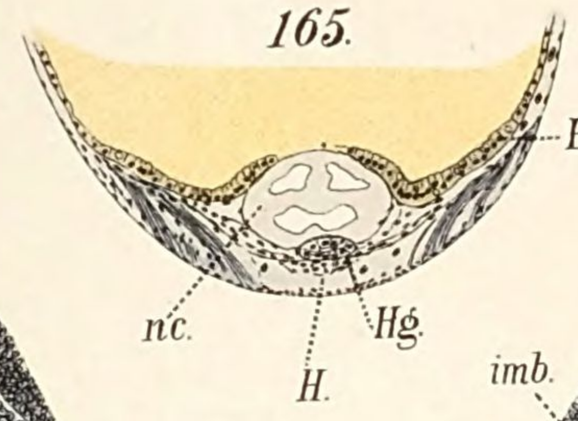
163.



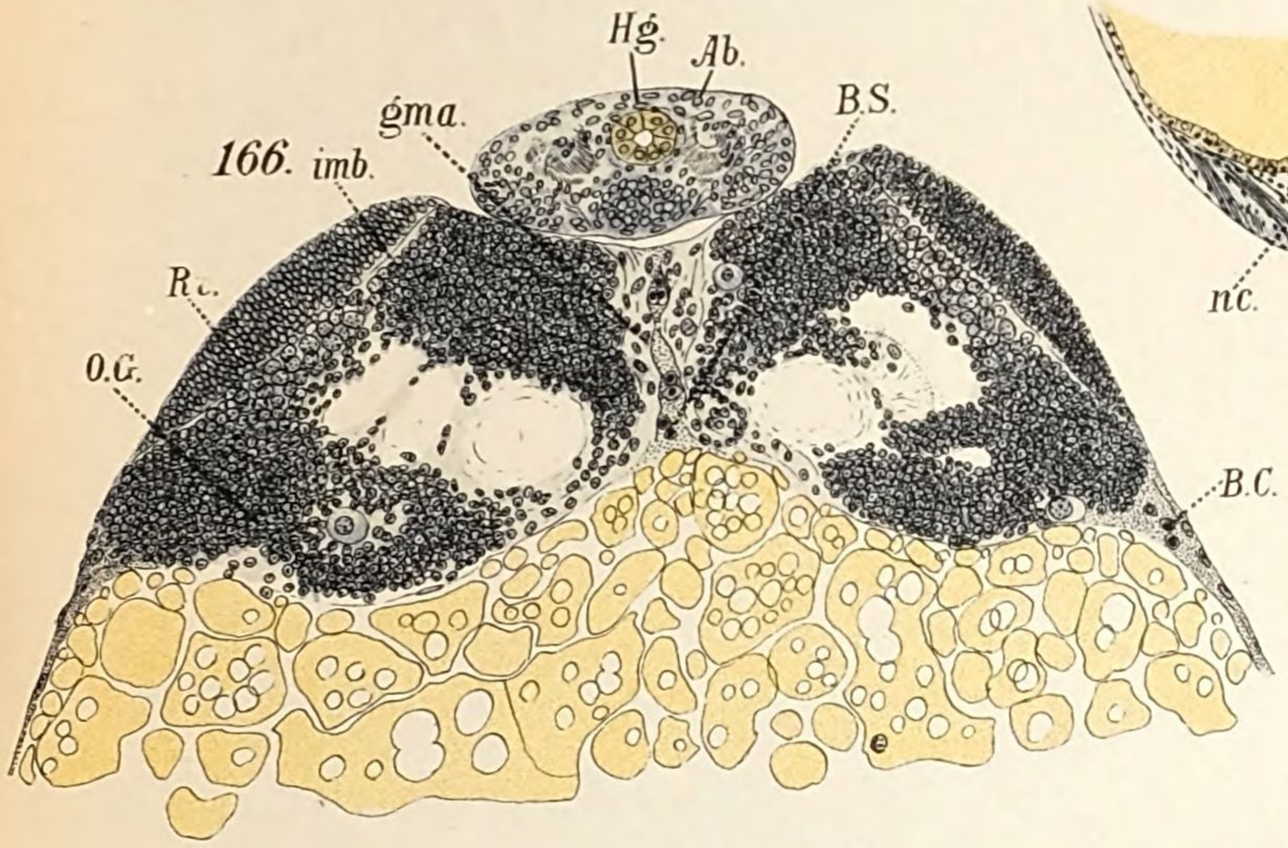
164.



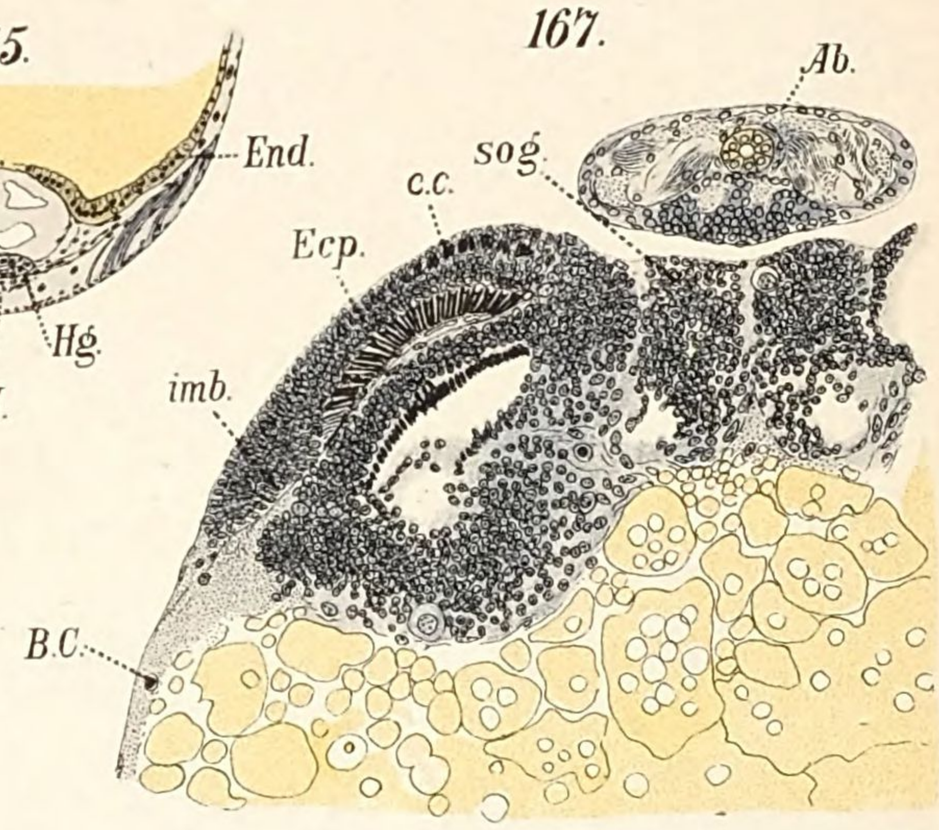
165.



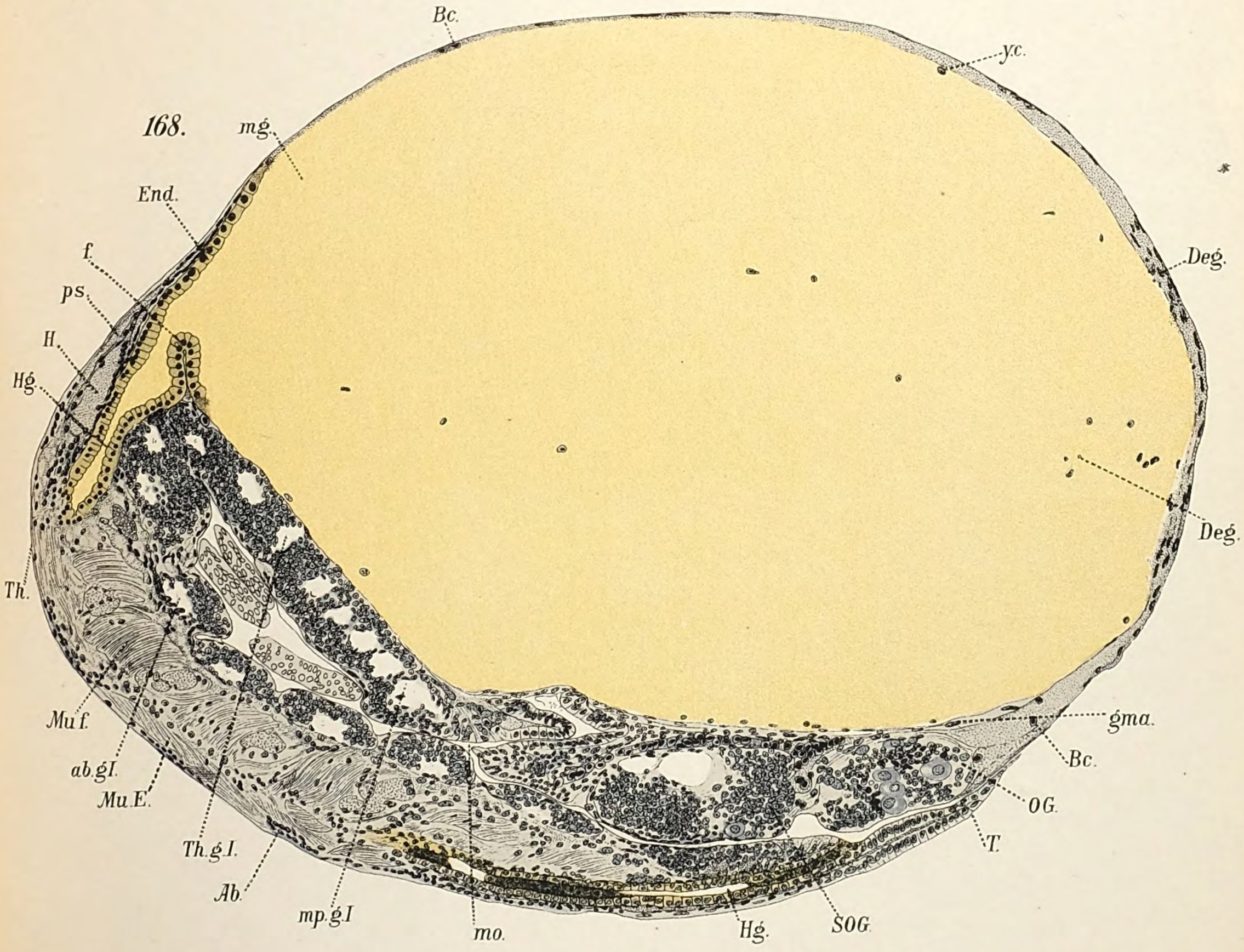
166.



167.



168.



F. H. Herrick, del.

ALPHEUS

Plate XLIX.

(Stages X and XII.)

Figs. 169–173. Parts of serial transverse sections through the embryo of *Alpheus saulcyi* in Stage X. In Fig. 173 the reproductive organ *R. O.* is cut. ×129, (Fig. 173, ×234.)

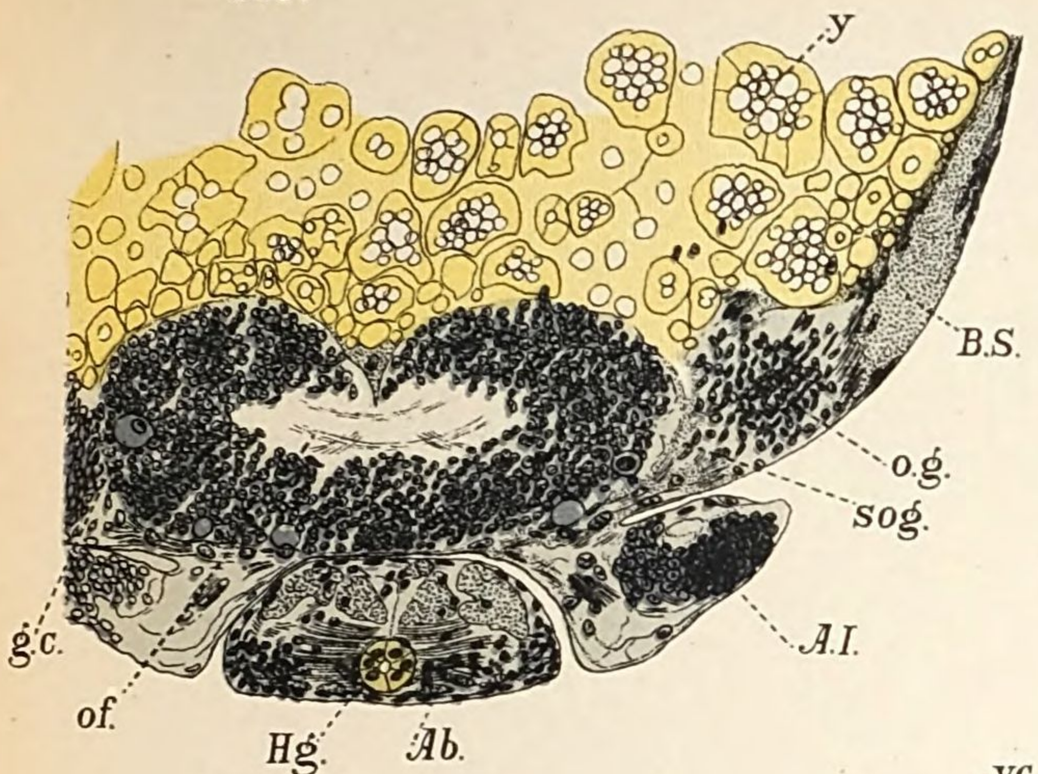
Fig. 174. Horizontal section through nervous system of the first larva, on a level with the œsophageal commissures. ×234.

Figs. 175, 176. Transverse sections through the neural cord of the first larva. In Fig. 176 the transverse commissure of the ganglia of the tenth segment is cut and in Fig. 175 the short longitudinal commissures between the tenth and eleventh segments are sectioned. ×129.

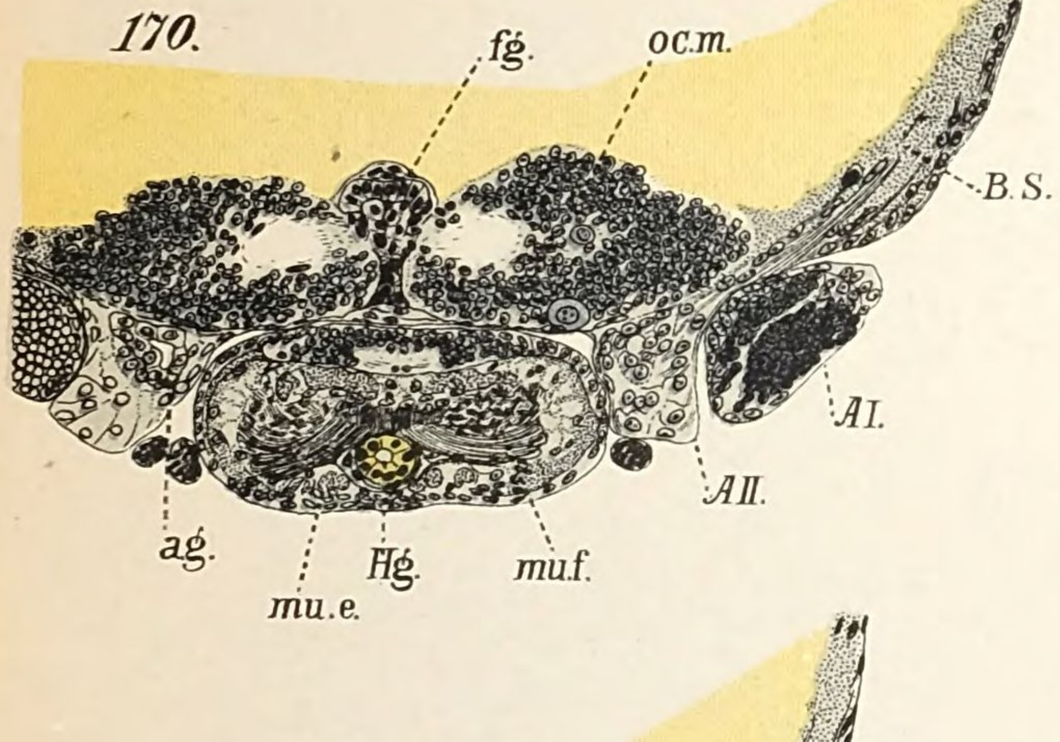
REFERENCE LETTERS.

A. I, first antenna.
A. II, second antenna.
Ab., abdomen.
ag., antennal gland.
B. c., blood corpuscles.
B. S., blood sinus.
Br., branchia.
cp., carapace.
End., endoderm.
fg., foregut.
g. c., ganglion cell.
Hd., hypodermis.
Hg., hindgut.
l. f., lateral fiber-mass of brain.
Md., base of mandible.
Mes., mesoderm.
Mg., mesenteron.
Mu., muscle.
Mu. e., extensor muscles of abdomen.
Mu. f., flexor muscles of abdomen.
Mx., base of maxillæ.
Mxpd., base of maxillipeds.
n. c., neural cord.
of., optic fiber-mass of brain.
o. g., optic ganglion.
Pr., perineurium.
R. O., reproductive organ.
sog., brain.
t. c., transverse commissure.
y. c., wandering cells.

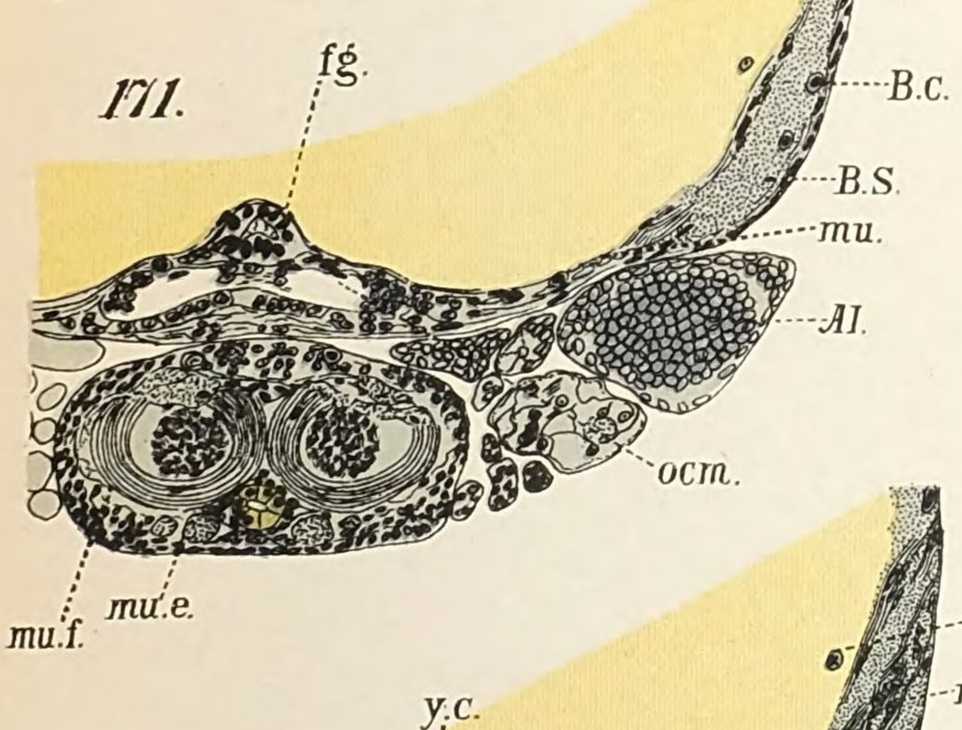
169.



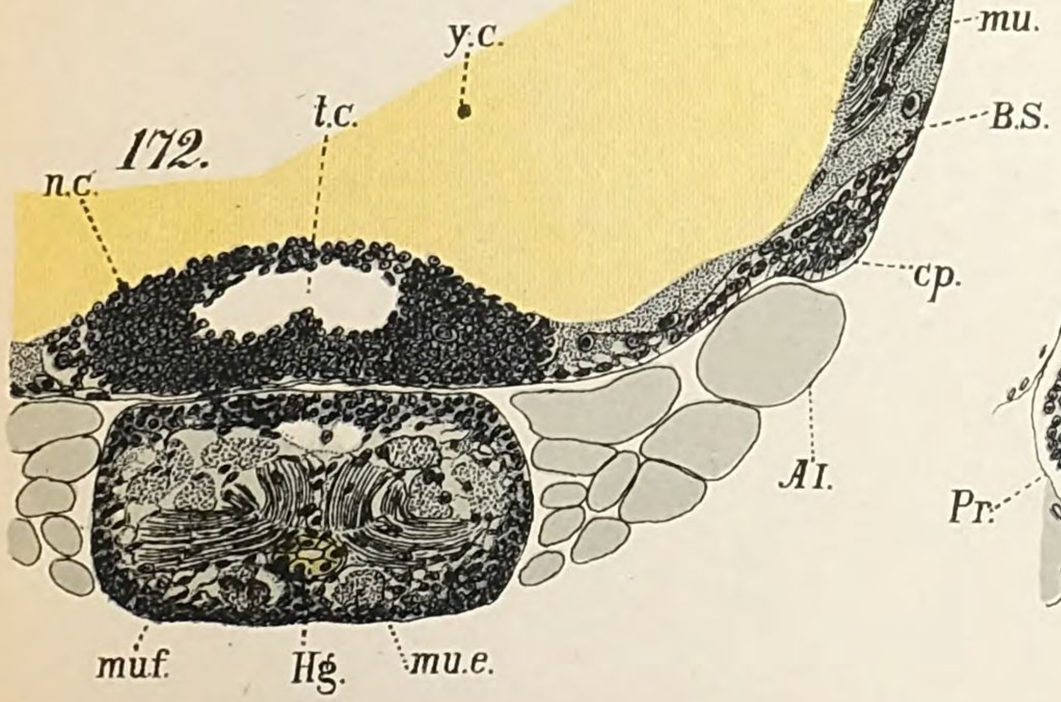
170.



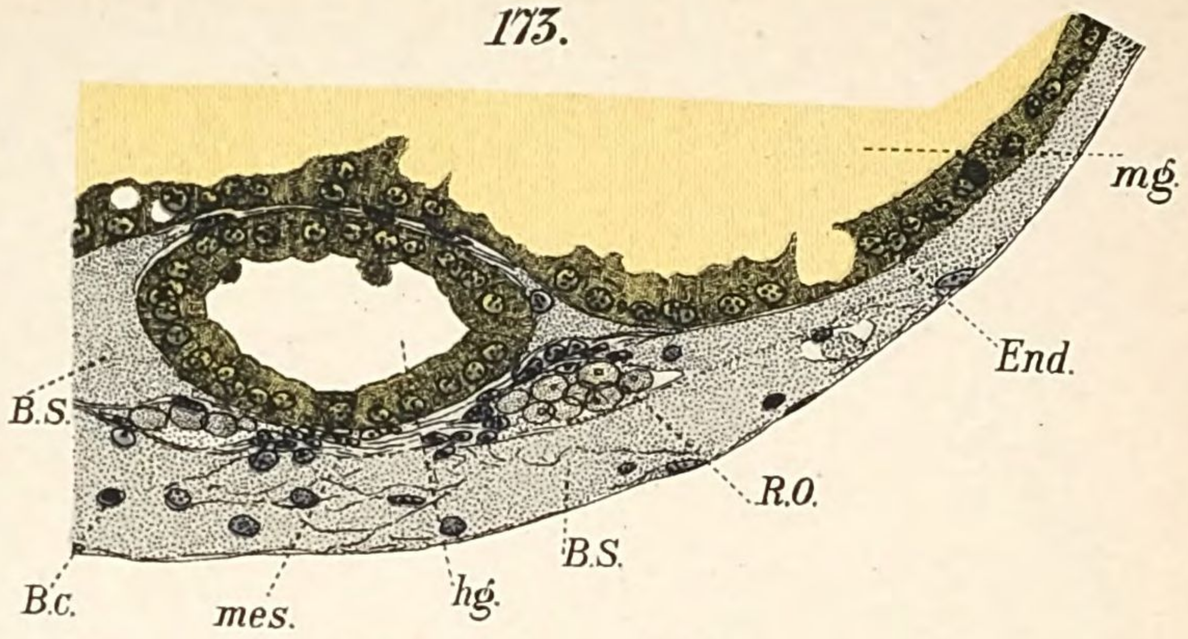
171.



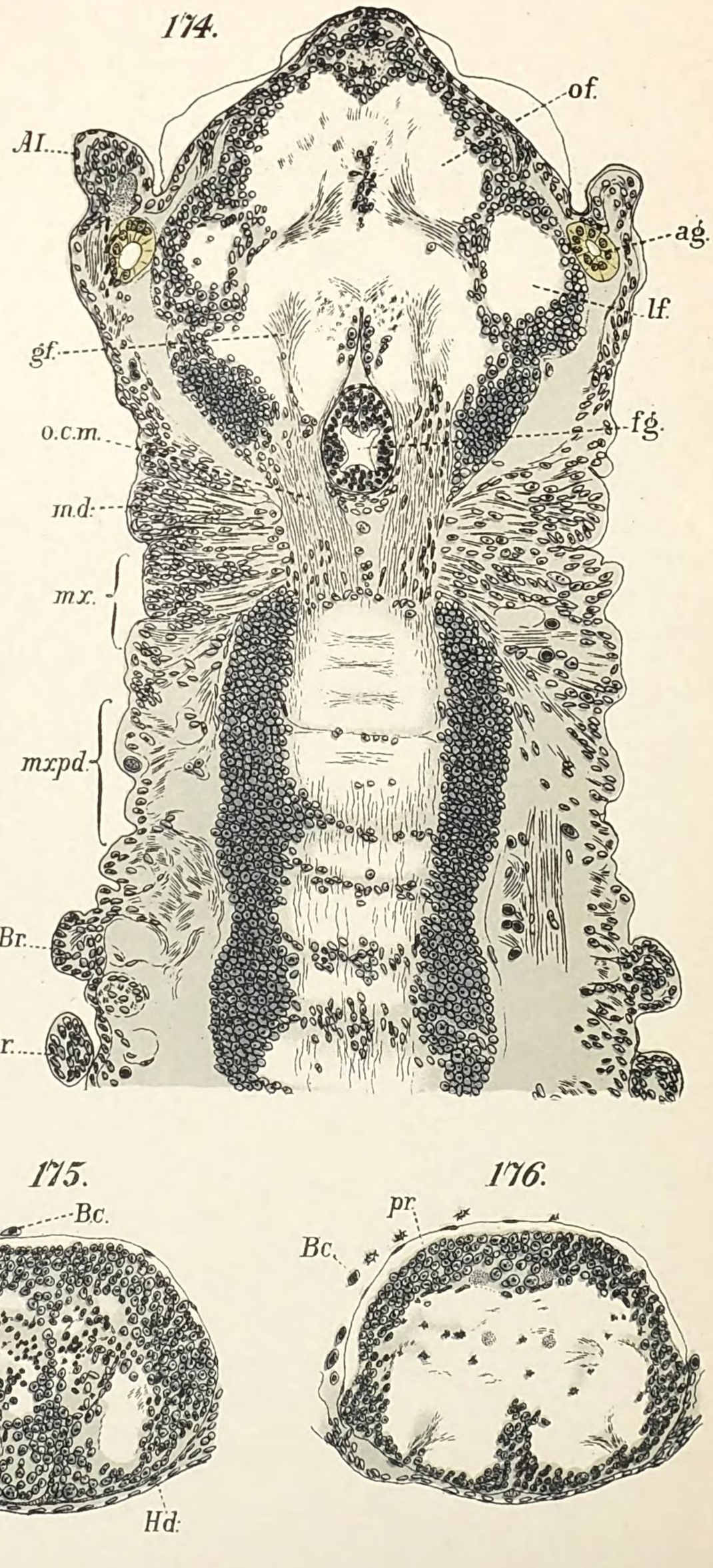
172.



173.



174.



175.

176.

F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

PLATE L.

(Stage XI.)

FIGS. 177–179, 181, 182. Serial transverse sections of the embryo of *Alpheus heterochelis*, which is nearly ready to hatch. The shell is somewhat diagramatically represented and appears thickened in Fig. 182, owing to a coagulable substance beneath it. The cells represented in the yolk in Fig. 182 appear to be endoderm cells, which have become mechanically detached from the walls of the mesenteron. ×74.

FIG. 180. Nearly median longitudinal section through a similar embryo. The endodermal lining of the mesenteron is not yet nearly completed. ×74.

REFERENCE LETTERS.

Ab., VI, ganglion of sixth abdominal appendage.
ag., antennal ganglion.
ans., anus.
ch. ex., external chiasma.
ect., ectoderm.
end., endoderm.
fg., foregut.
gma., anterior gastric muscle.
H., heart.
hg., hindgut.
hy., hypodermis.
lf., lateral fiber-mass of brain.
mg., mesenteron.
$mg.^1$ $mg.^3$ of other figures, posterior lobe of midgut.
mu. f., flexor muscles of midgut.
mu. e., extensor muscles of midgut.
ocm., œsophageal commissure.
o. pd., optic peduncle.
Ret., retina.
sog., brain.
T., telson.
1–4, ganglia of eye-stalk.

Fig. 177.

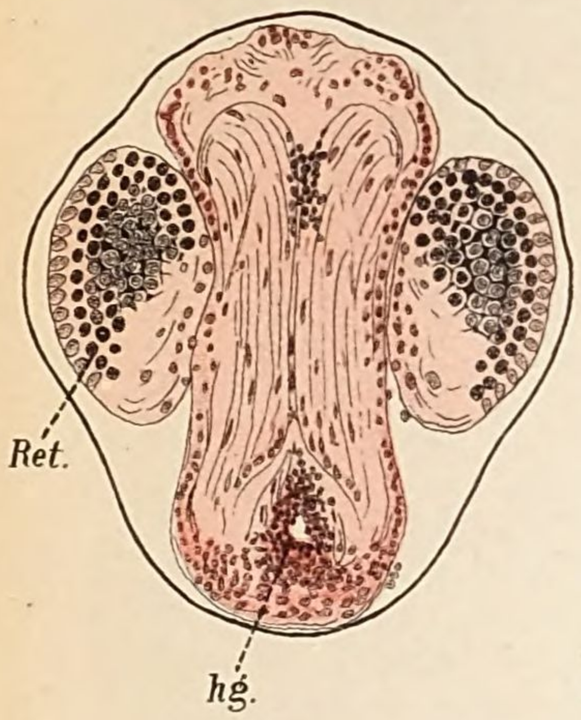


Fig. 178.

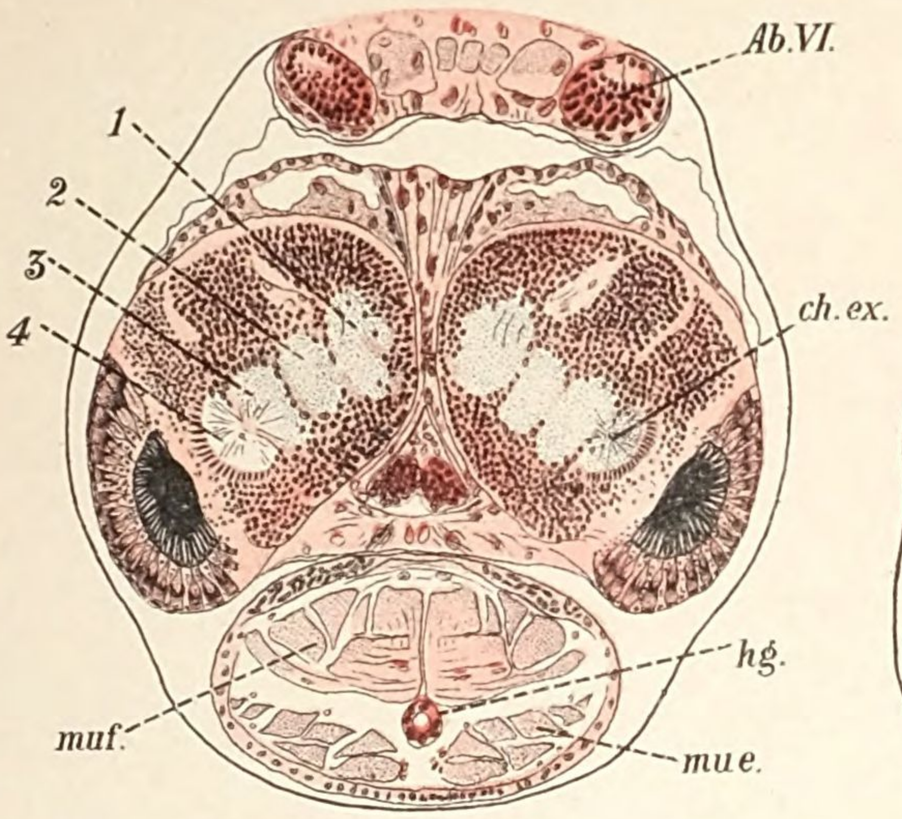


Fig. 179.

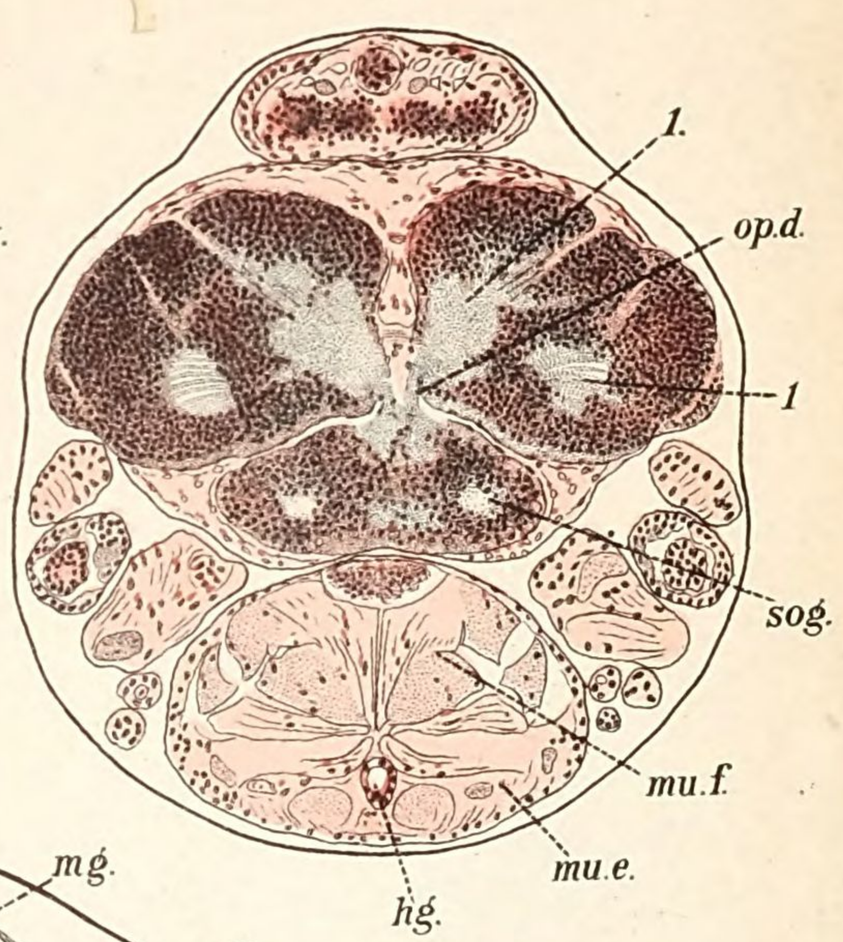


Fig. 180.

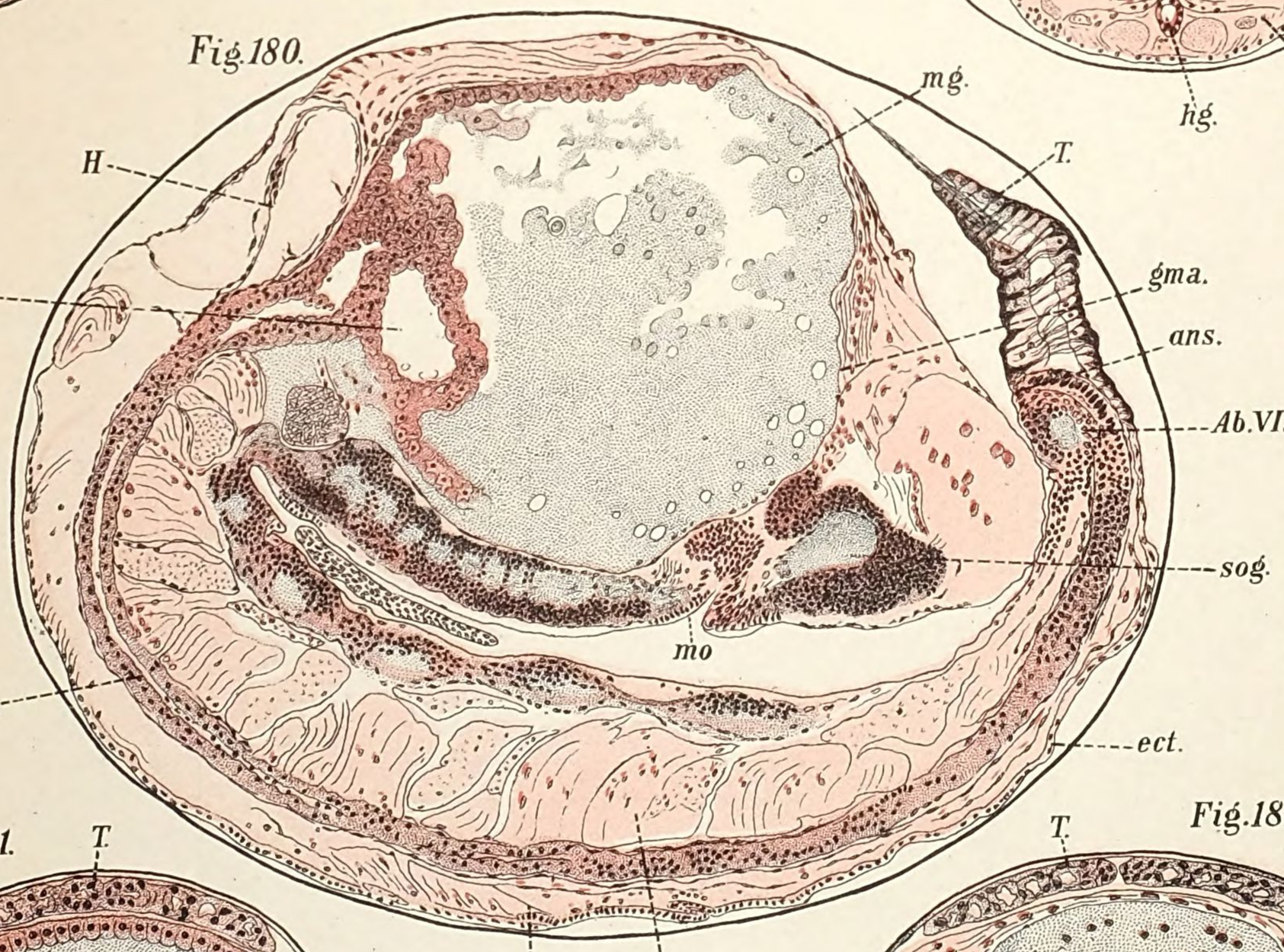


Fig. 181.

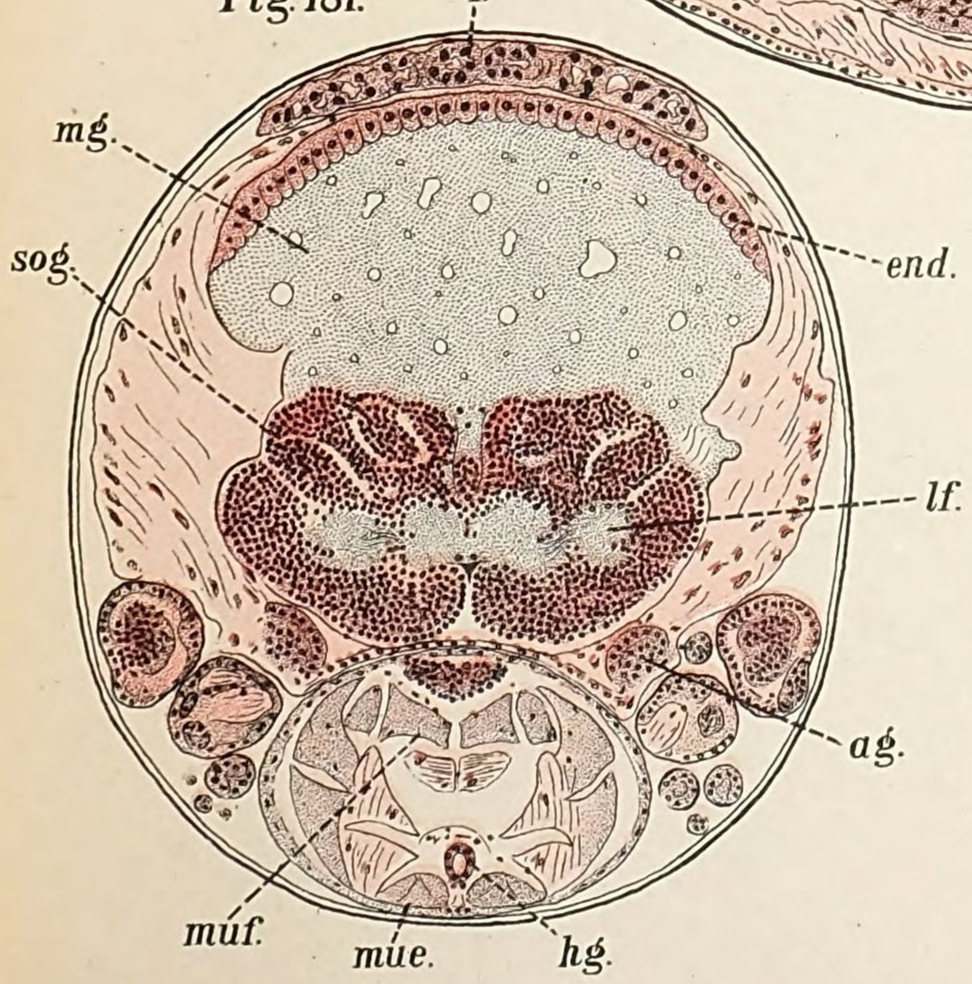
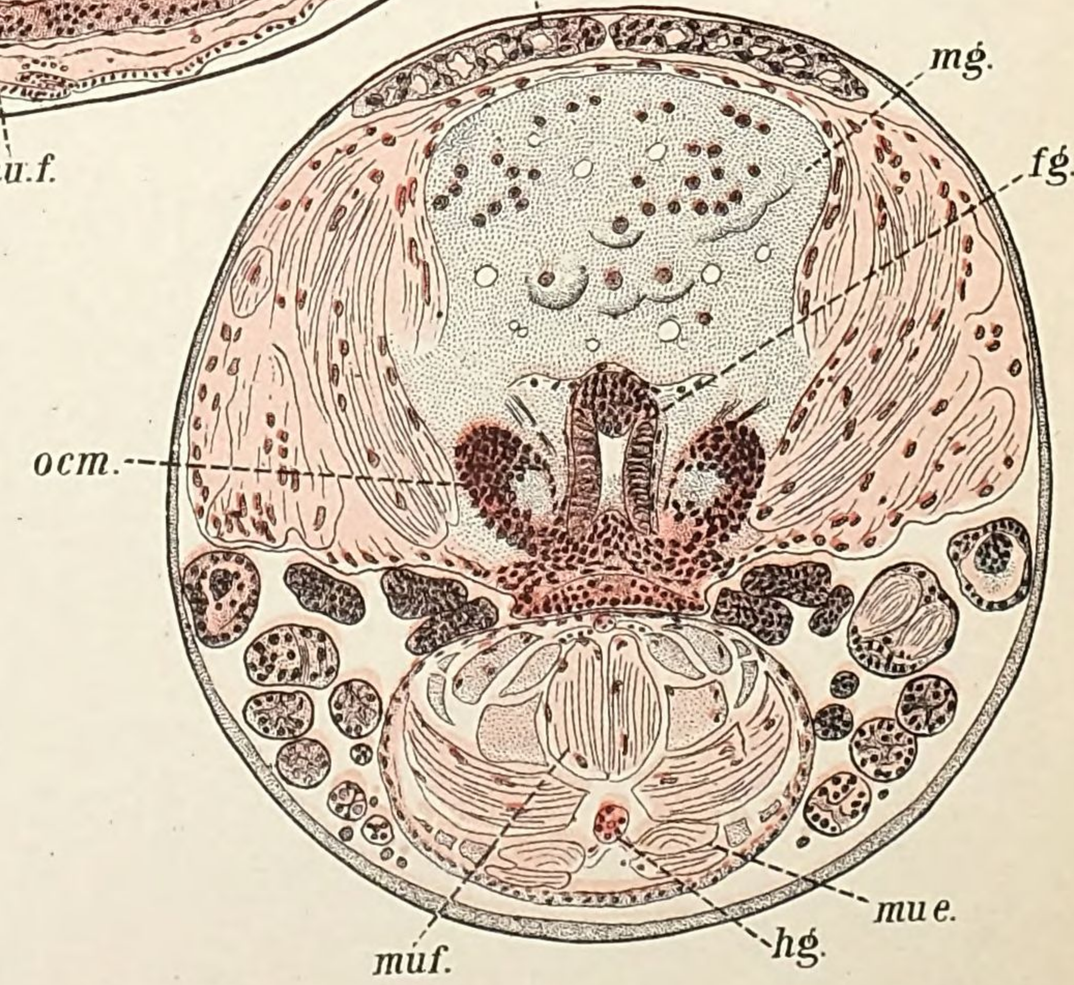


Fig. 182.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS HETEROCHELIS.

Plate LI.

(Stage XI.)

Figs. 183–186. Continuation of series of transverse sections of embryo begun on Plate L. ×74.

Fig. 187. Part of sagittal section of similar embryo, cutting eyestalk somewhat obliquely. The specimen was depigmented in nitric acid. The distal retinular cells, occupying the spaces (*Pg. c.*) between the peripheral ends of the cones, are not represented. ×305.

REFERENCE LETTERS.

ac. P., accessory pigment cells.
ad. m., adductor of mandible.
a. sa., superior abdominal artery.
bg., branchiostegite.
b. v., blood vessel.
c., crystalline cone.
cg., corneagen.
ect., ectoderm.
end., endoderm.
fg., foregut.
H., heart.
hy., hypodermis.
imb., intercepting membrane.
mg., midgut.
mg.^{3}, posterior lobe of midgut.
Mu., muscle of eyestalk.
Mu. e., extensor muscles of abdomen.
Mu. f., flexor muscles of abdomen.
o. c. m., œsophageal commissure.
Pg. C., position of distal retinular cells.
Ps., pericardial sinus.
Rtu., proximal retinular cells.
Rtu.^{1}, nuclei of proximal retinular cells.
3, 4, ganglia of eyestalk.

Fig. 183.

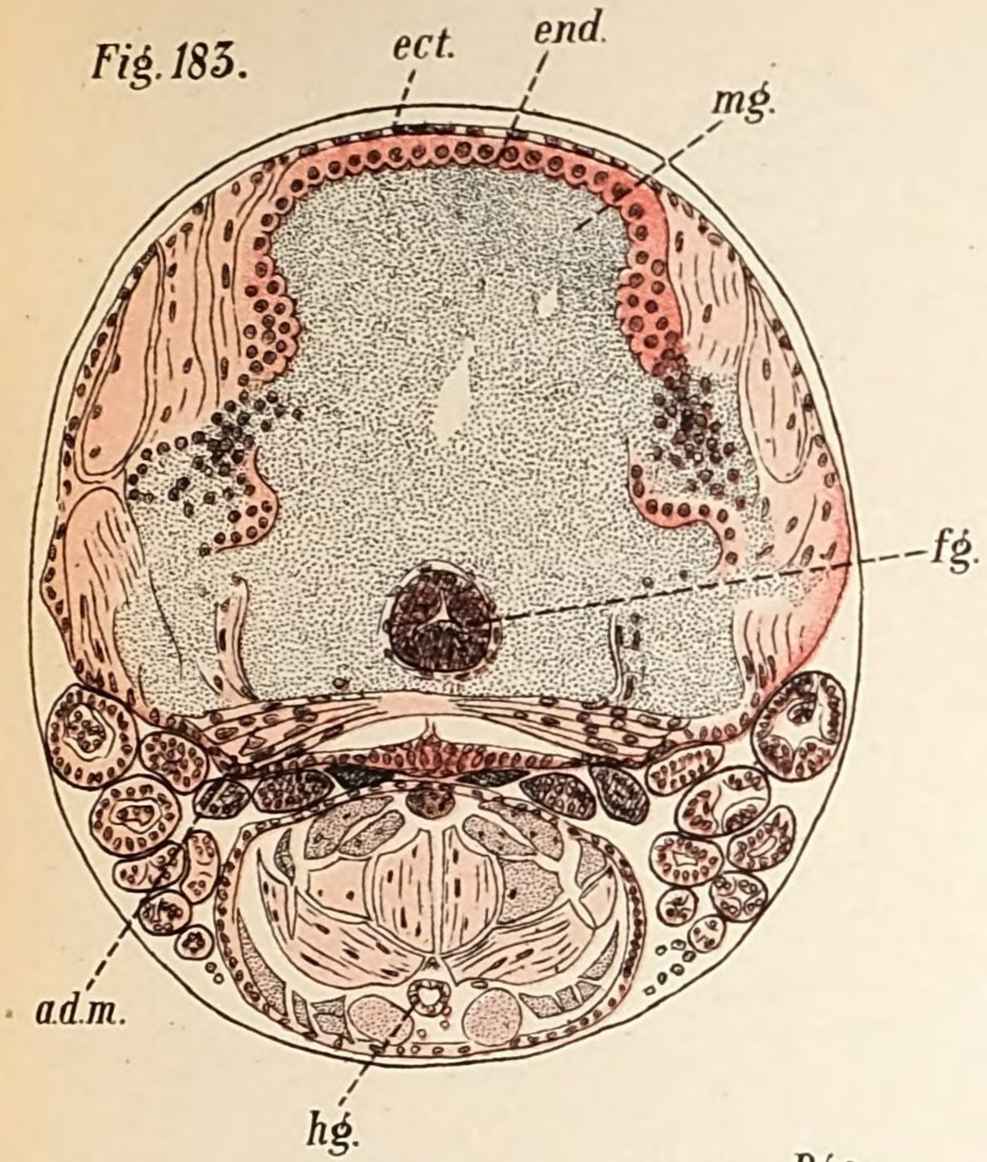


Fig. 184.

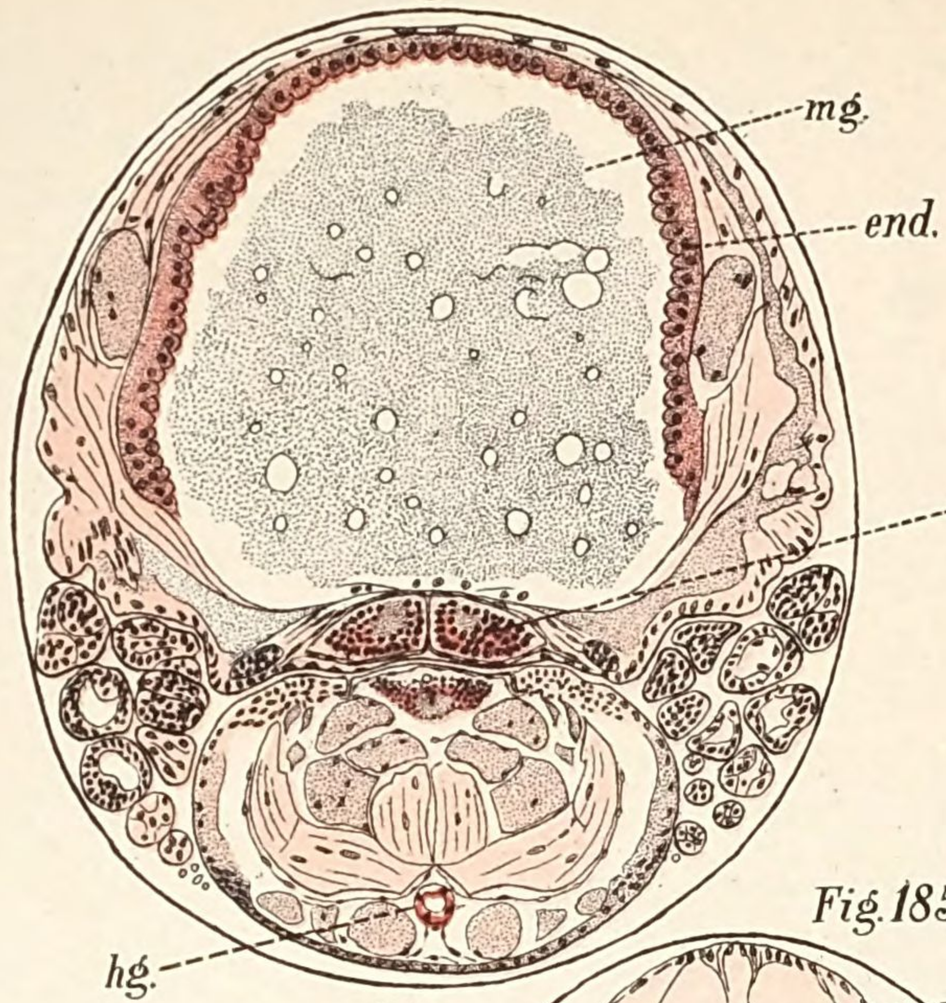


Fig. 185.

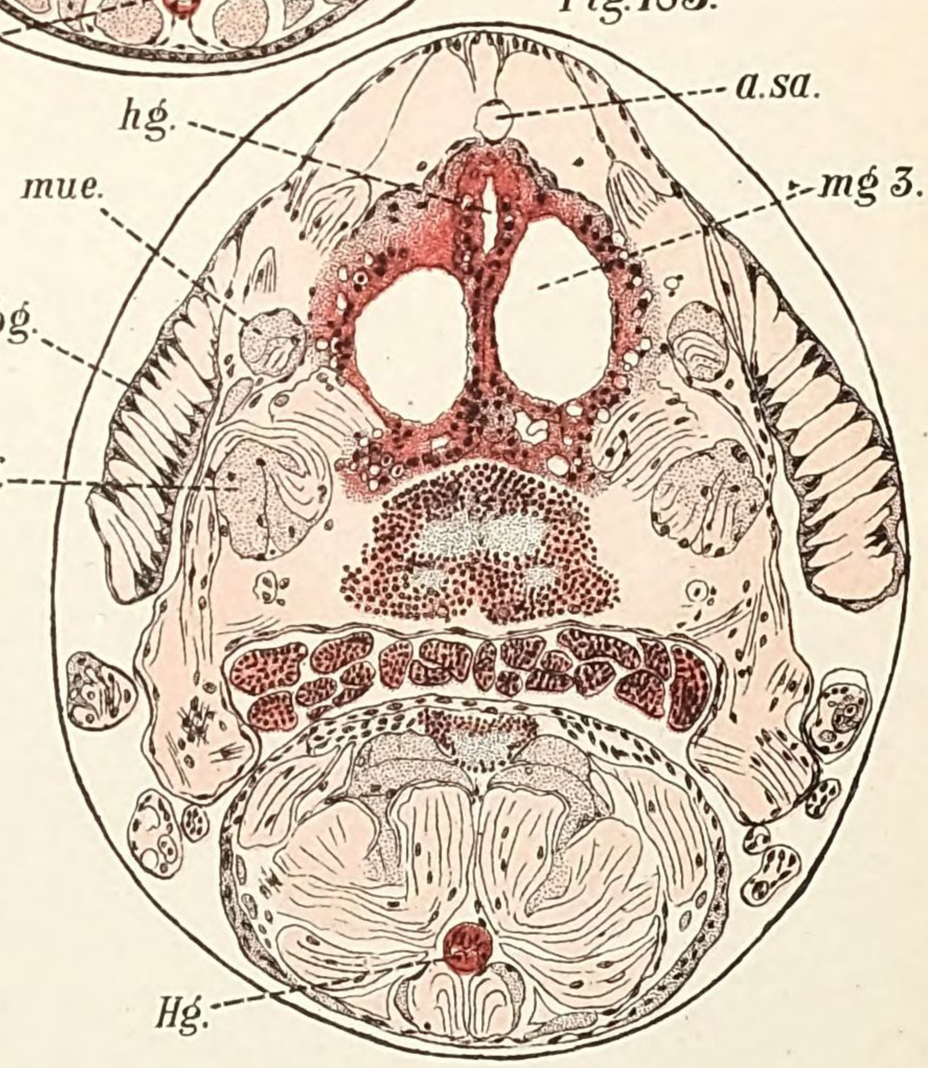


Fig. 187.

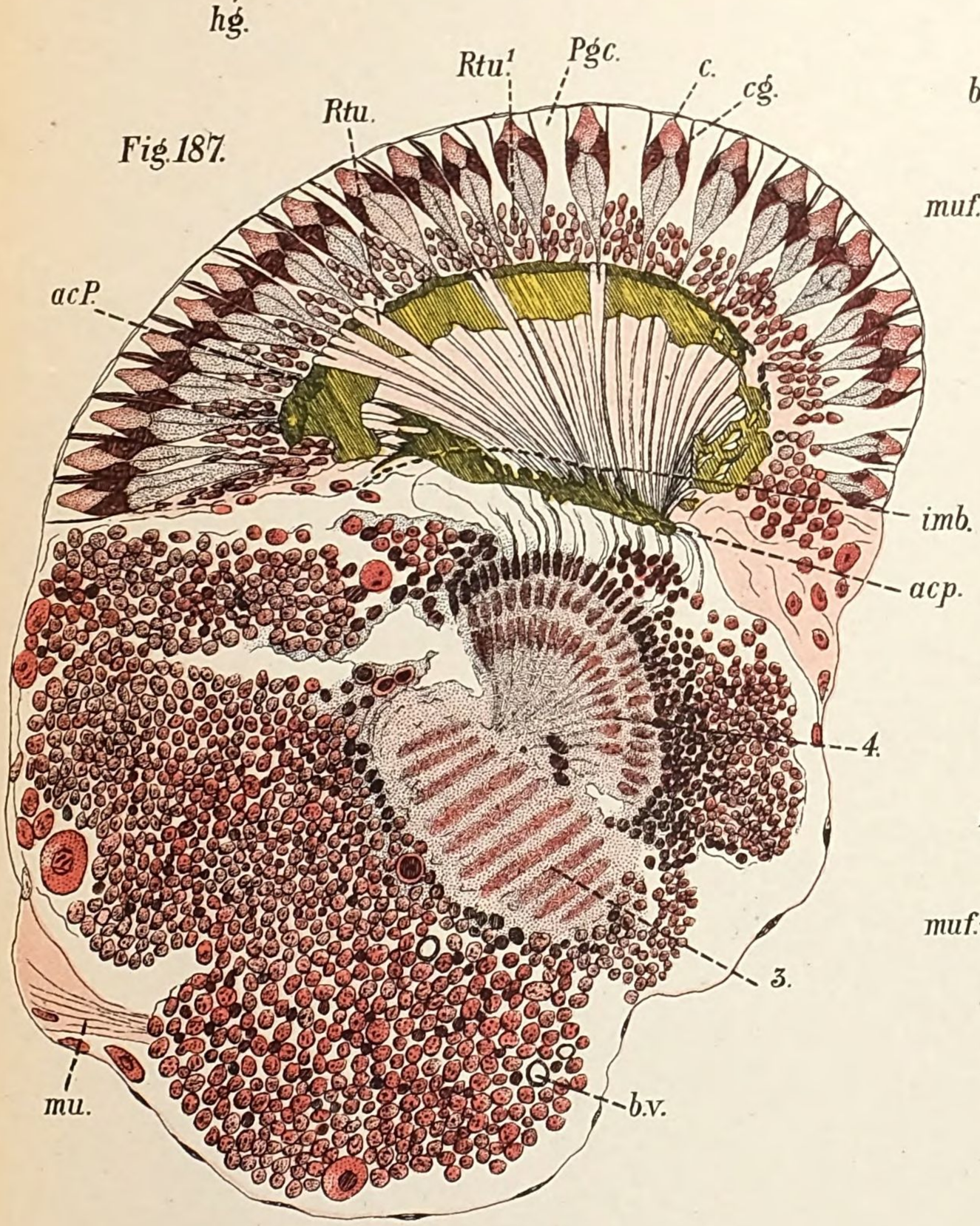
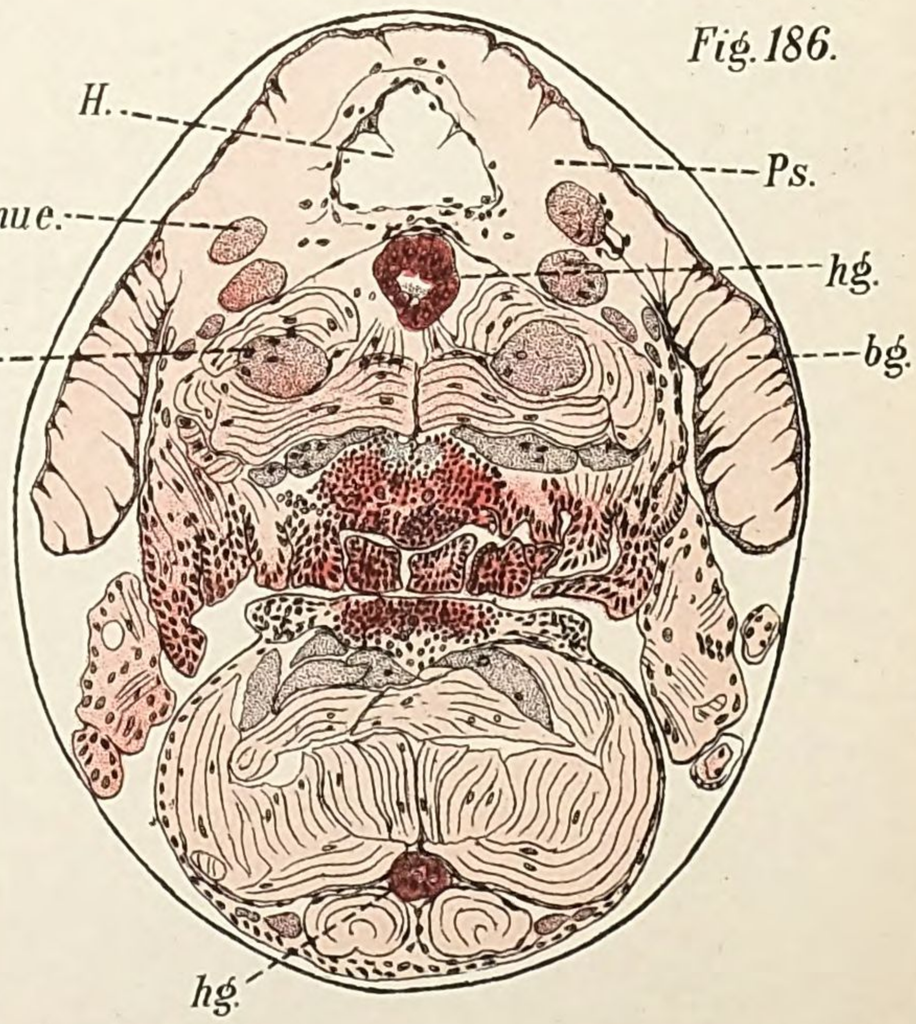


Fig. 186.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS

PLATE LII.

FIGS. 188, 189. Parts of transverse serial sections through the embryo of *Palæmonetes vulgaris*, at the stage when pigment is just appearing in the eyes. In the anterior section (Fig. 188) the retinogen is a unicellular layer. ×305.

FIGS. 190–191. Parts of serial transverse sections through the brain, the optic ganglia, and eye of an embryo of *Alpheus heterochelis*. In the anterior section (Fig. 190) the clusters of cells which represent the ommatidia are well shown. Numerous ganglion cells are dividing. ×305.

FIG. 192. Part of transverse section through eye, optic ganglion, and brain at a later stage. ×305.

REFERENCE LETTERS.

A. I, first antenna.
Ab., abdomen.
cc., crystalline cone cells.
imb., intercepting membrane.
mes., mesoderm.
Ret., retina.
rtl.[1], rudimentary eighth proximal retinular cell.
sog., brain.
T., telson.
X., stratum of large ganglion cells.
1, 3, 4, proximal, external middle, and distal segments of optic ganglion.

Fig. 188.

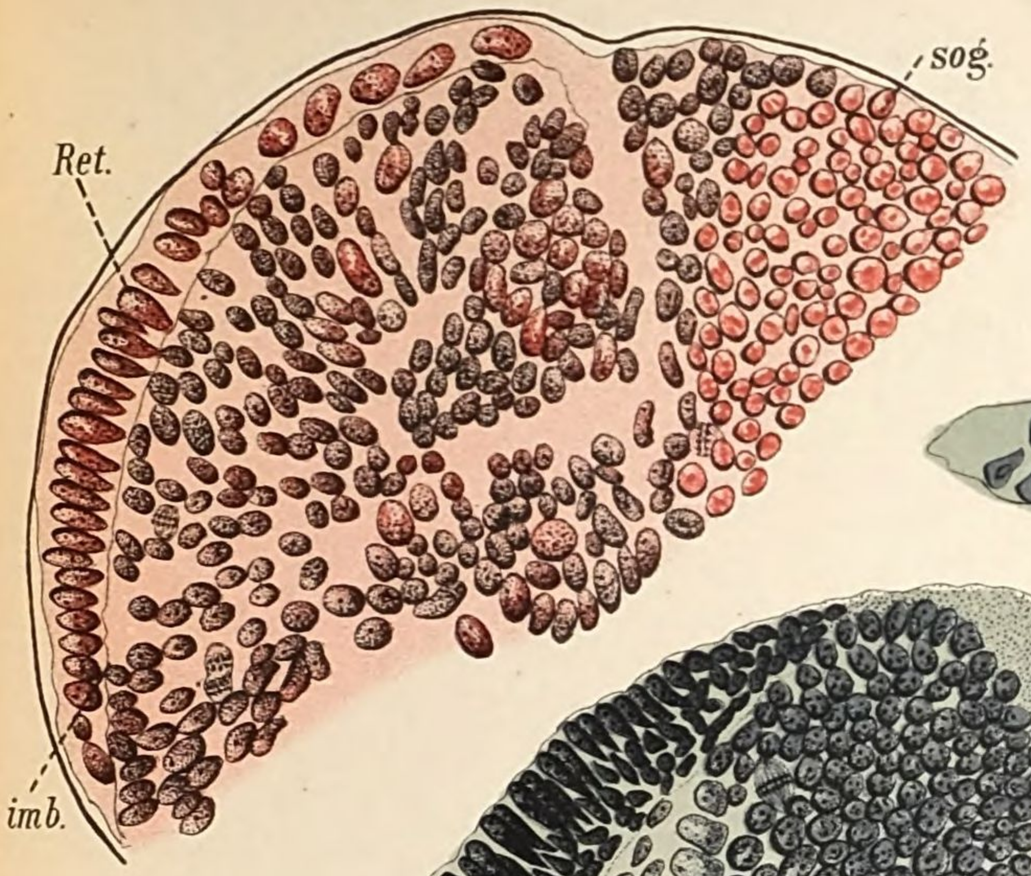


Fig. 189.

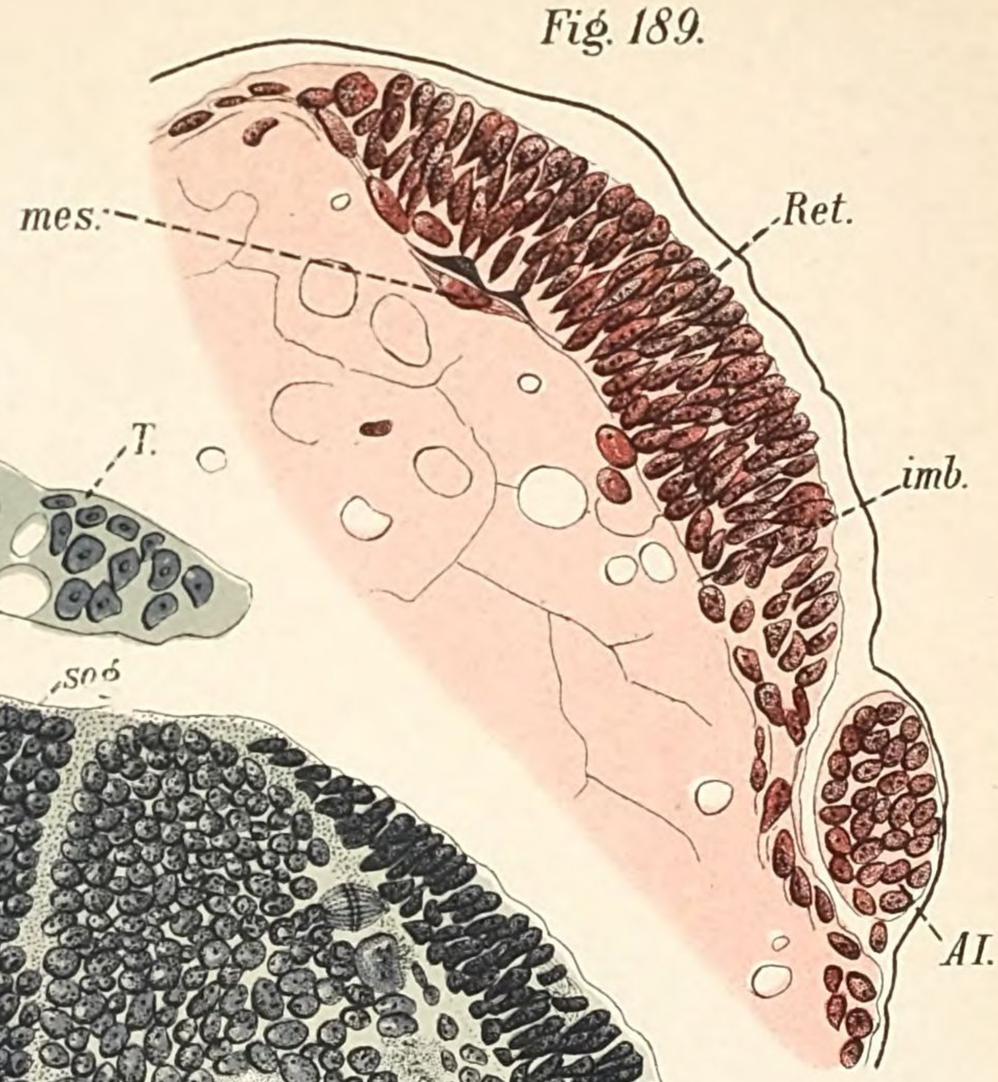


Fig. 190.





Fig. 191.

Fig. 192

F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

ALPHEUS AND PALAEMONETES.

Plate LIII.

FIG. 193. Part of transverse section through an embryo of *Alpheus saulcyi*, which is nearly ready to hatch, showing the third left branchia covered by the branchiostegite. ×289.

FIG. 194. Part of sagittal section of eyestalk of a slightly younger embryo. ×289.

FIG. 195. Part of transverse section, showing branchia, of the third larva of *Alpheus saulcyi* (twenty-four hours old). ×289.

FIG. 196. Nearly median longitudinal section of first larva of same. The anterior lobes of the midgut (mg^1) still contain unabsorbed yolk. Compare Pl. XXI, Fig. 1. ×58.

FIG. 197. Part of transverse section, showing the papilla, which bears the median eye in the first larva of same. ×289.

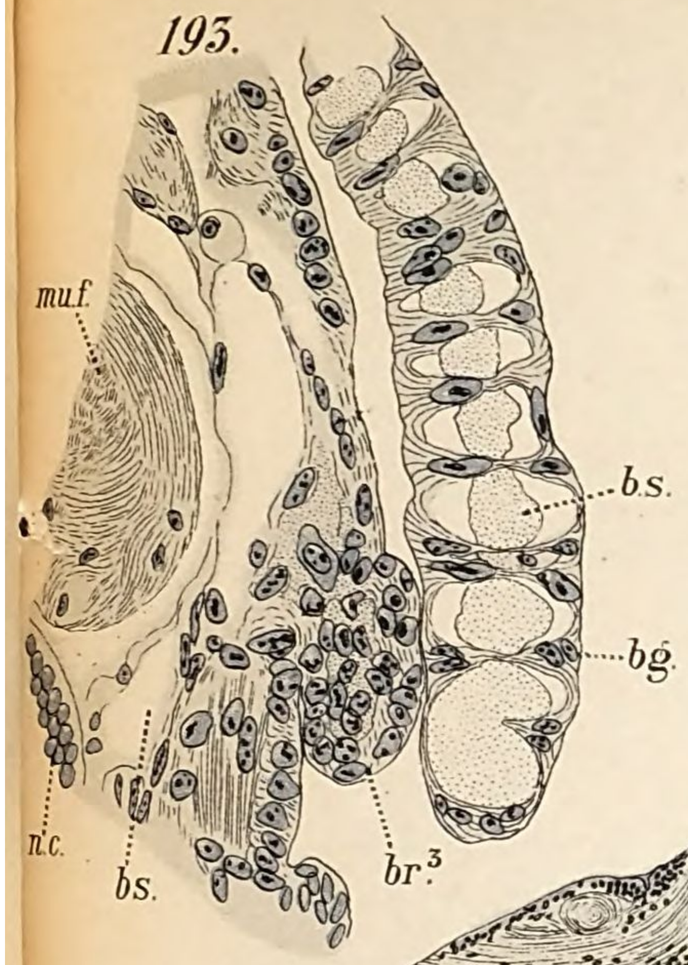
FIG. 198. Transverse section of first larva, cutting the lateral fiber balls of the brain, the anterior lobes of the midgut, and the green gland. ×289.

FIG. 199. Part of transverse section through an advanced embryo of *Alpheus saulcyi*, parasitized by a fungus, most of the cells of which are encysted. From brown sponge, Abaco, Bahama Islands. v, Appendix II. ×186.

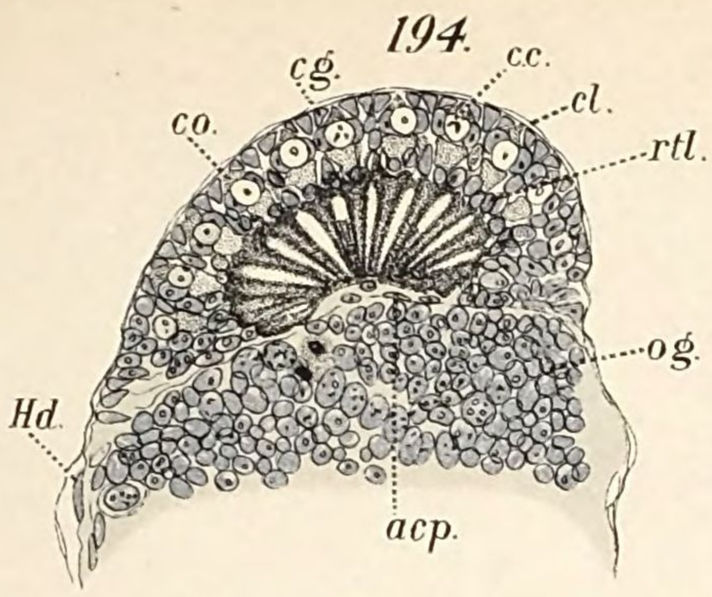
REFERENCE LETTERS.

ab., abdomen.
Ab. VI, sixth abdominal appendage.
acp., accessory pigment cells.
ag., green gland.
ag. s., end sac (?) of gland.
as. a., superior abdominal aorta.
bg., branchiostegite.
b. s., *B. S.*, blood space.
$br.^3$, branchia of third left ambulatory limb.
cc., crystalline cone cells.
cg., corneagen.
cl., lens.
co., crystalline cone.
cs., $cs.^{1-2}$, cysts of parasite.
$cs.^3$, smaller, naked cells of parasite.
$g.^{4-20}$, segmental ganglia.
gf., fiber-mass of second antennæ.
gma., anterior gastric muscle.
H., heart.
Hd., hypodermis.
Hg., hindgut.
Lb., labrum.
l. c., longitudinal commissure.
mg., midgut.
$mg.^1$, anterior lobes of midgut.
$mg.^2$, lateral lobes of midgut.
$mg.^3$, posterior lobes of midgut.
mo., mouth.
ms., masticatory stomach.
mu. e., extensor muscles of abdomen.
mu. f., flexor muscles of abdomen.
n. c., neural cord.
oc., ocellus.
oe., œsophagus.
O. G., *o. g.*, optic ganglion.
of., optic enlargement of brain.
op., ophthalmic artery.
ps., pericardial sinus.
pr., perineurium.
R., rostrum.
Ret., retina.
rtl., nucleus of proximal retinular cell.
sog., brain.
Sp., parasitic growth.
St. s., sternal blood sinus.
T., telson.
y., yolk.

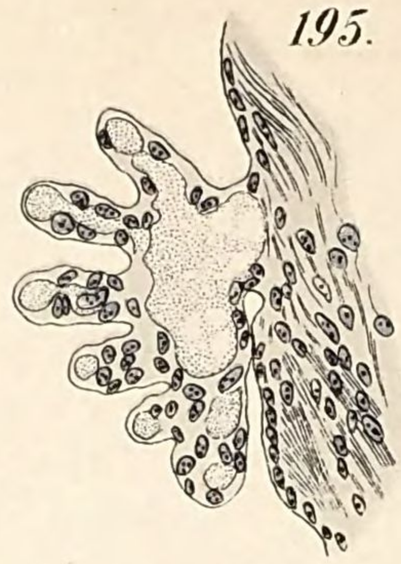
193.



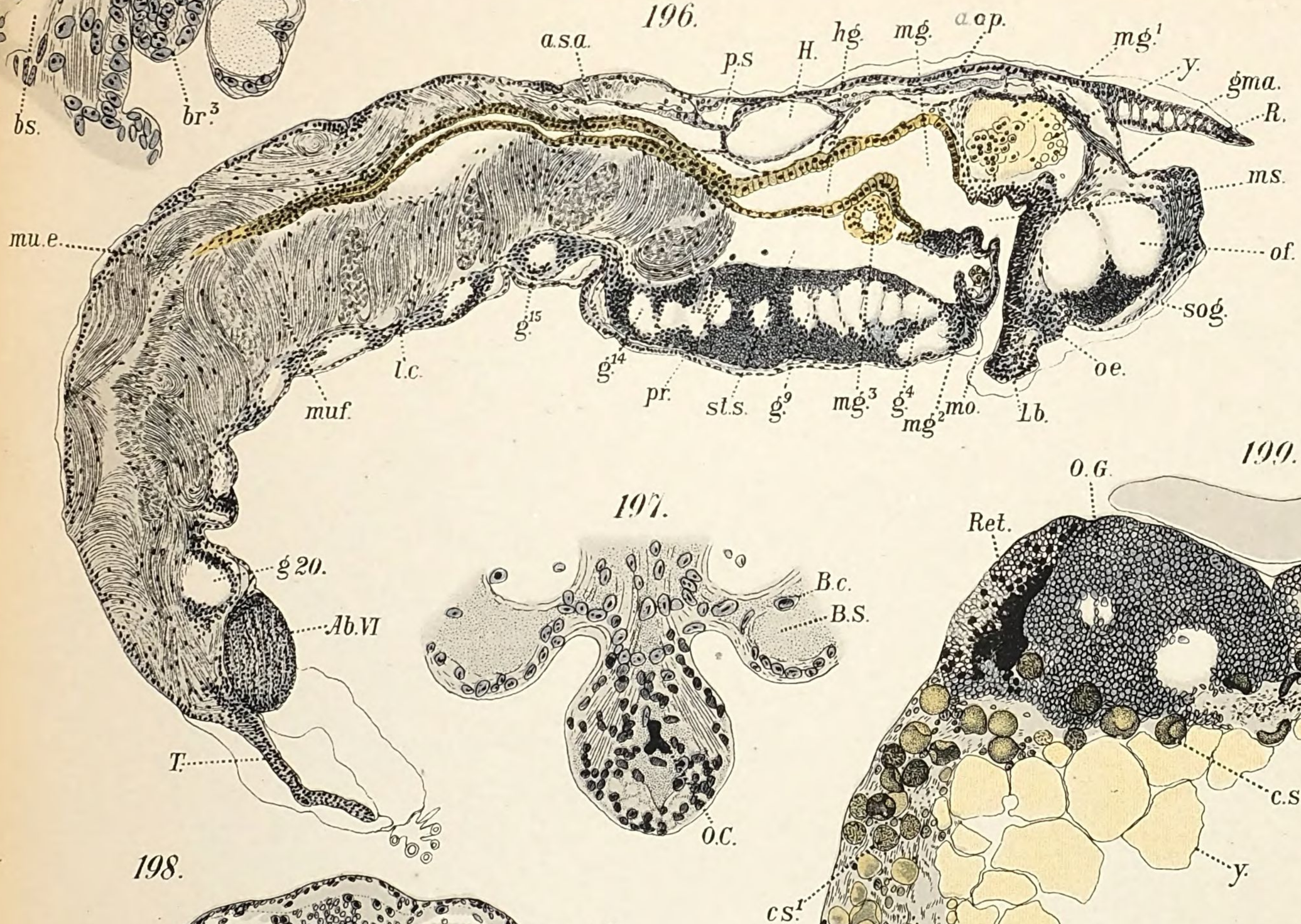
194.



195.

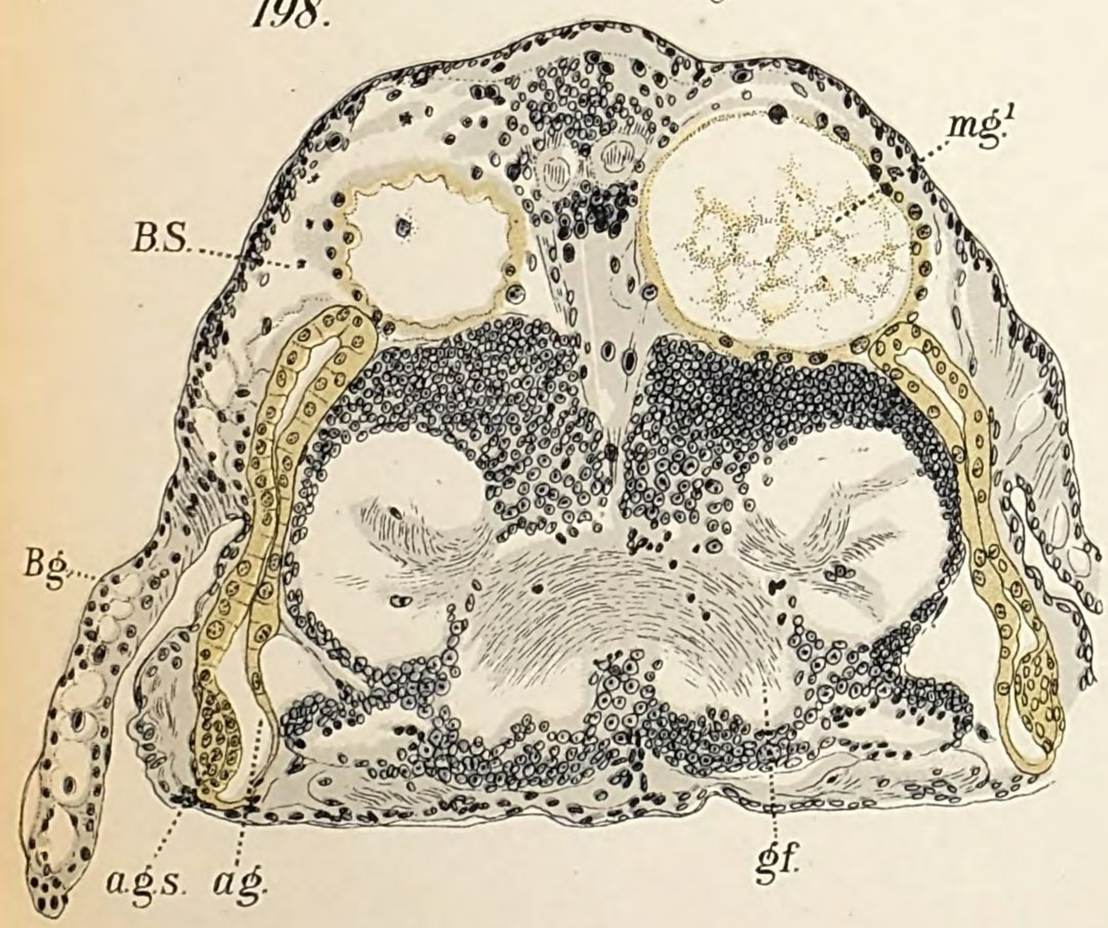


196.



197.

198.



199.

g 20.

Ab.VI

T.

F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS

PLATE LIV.

FIG. 200. Ommatidium of eye of small adult *Alpheus saulcyi* (from brown sponge); pigment removed by nitric acid. ×294.

FIGS. 201–204. Transverse sections through four adjacent ommatidia of first larva of same. In Fig. 201 the corneagen is cut, and in Fig. 202 the nuclei of the cone mother cells. In Fig. 204 the rhabdom is sectioned and the seven proximal retinular cells. ×294.

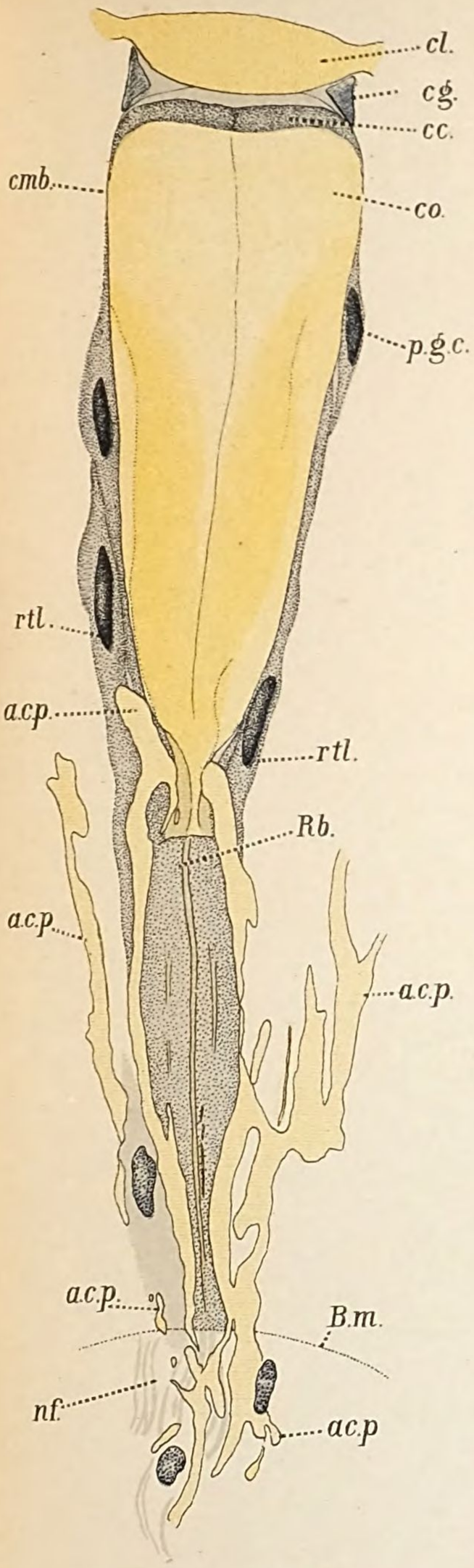
FIGS. 205–208. Transverse sections through adjacent ommatidia of the adult eye, taken at various levels. Fig. 205, the deepest section, shows the peculiar seven-pronged figure of the rhabdom. The proximal retinular cells appear in sections, as if fused together. ×294.

FIGS. 209–211. Transverse serial sections through the first larva of *Alpheus saulcyi*. ×74.

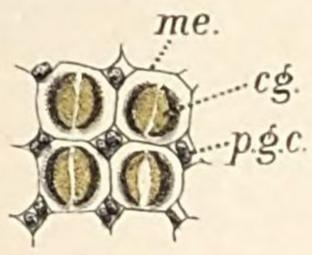
REFERENCE LETTERS.

A. I, first antenna.
A. II, second antenna.
a. cp., accessory pigment cell.
ac. pn., nucleus of accessory pigment cell.
ao., ear.
Bm., intercepting or basement membrane.
cc., crystalline cone cells.
cg., corneagen.
cl., lens.
Co., *co.*, crystalline cone.
cmb., cone membrane.
hd., hypodermis.
me., membrane of distal retinular cells.
nf., nerve fibers.
oc., ocellus.
og., optic ganglion.
of., optic enlargement of brain.
pap., papilla of ocellus.
p. g. c., distal retinular cells.
R., rostrum.
Rb., *rb.*, rhabdom.
Ret., retina.
rtl., proximal retinular cells.

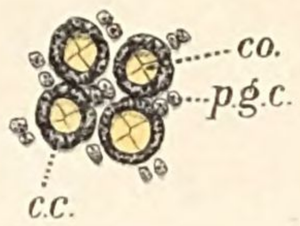
200.



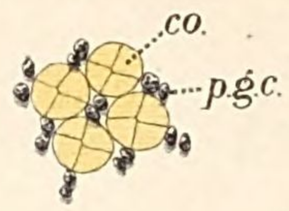
201.



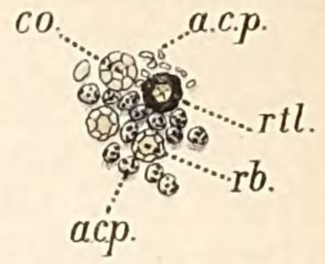
202.



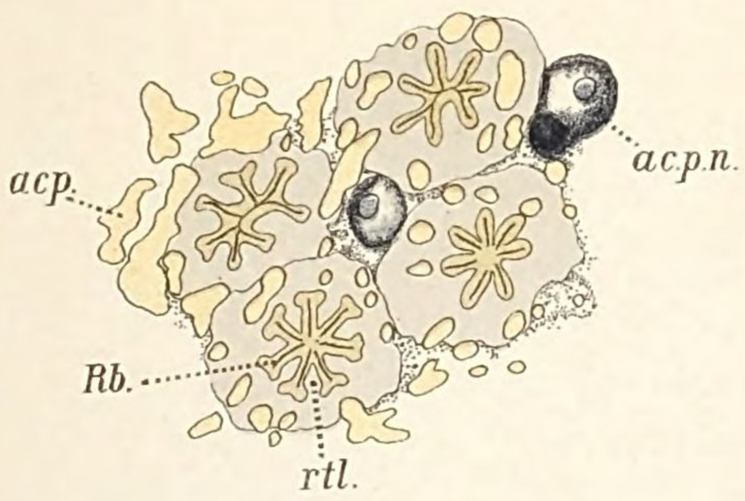
203.



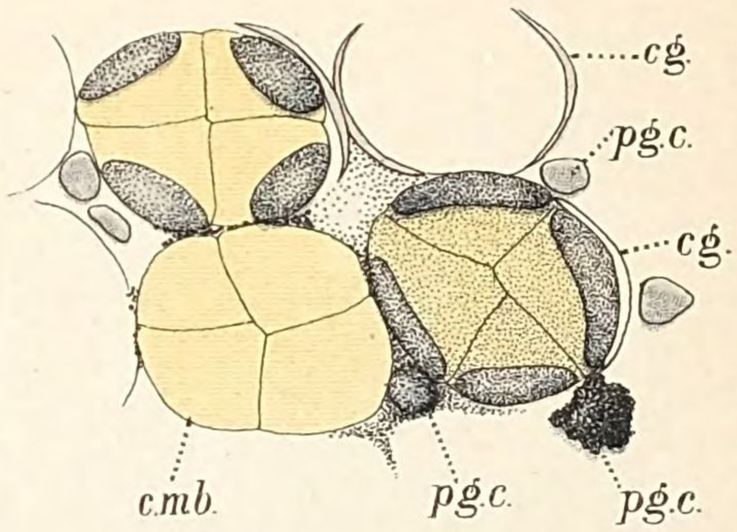
204.



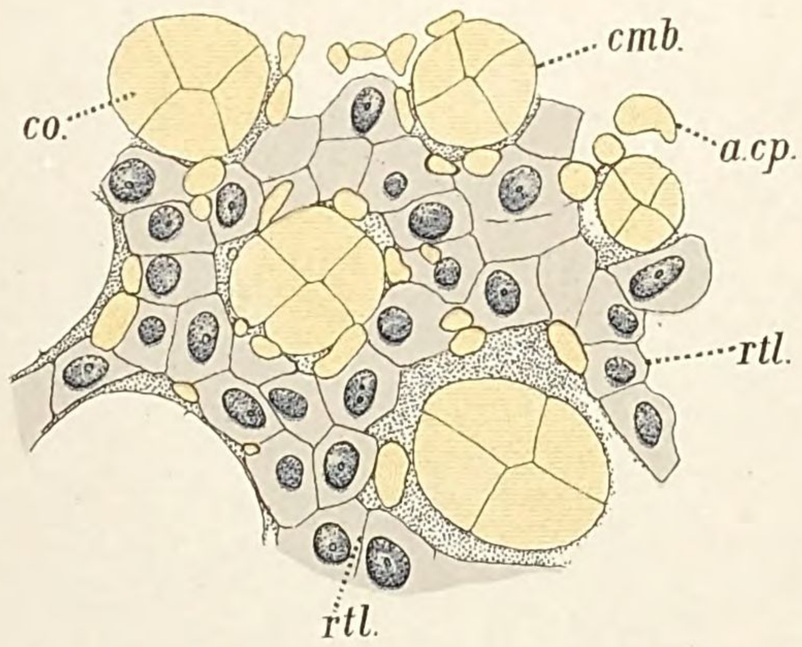
205.



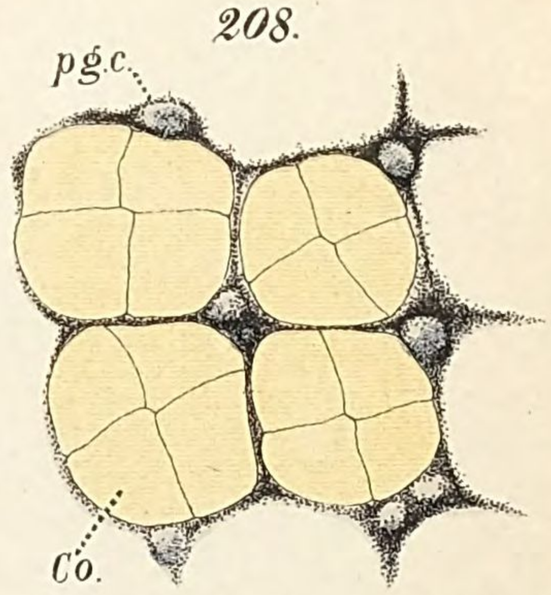
206.



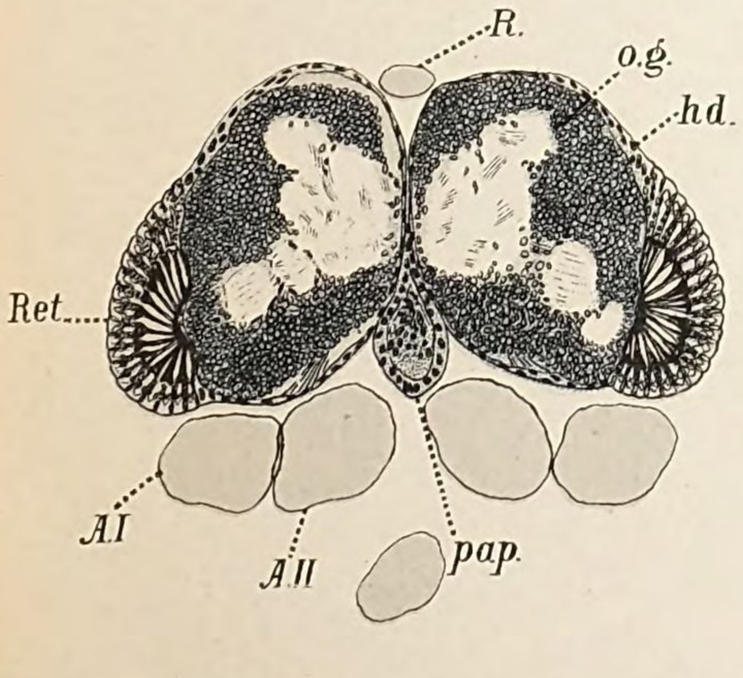
207.



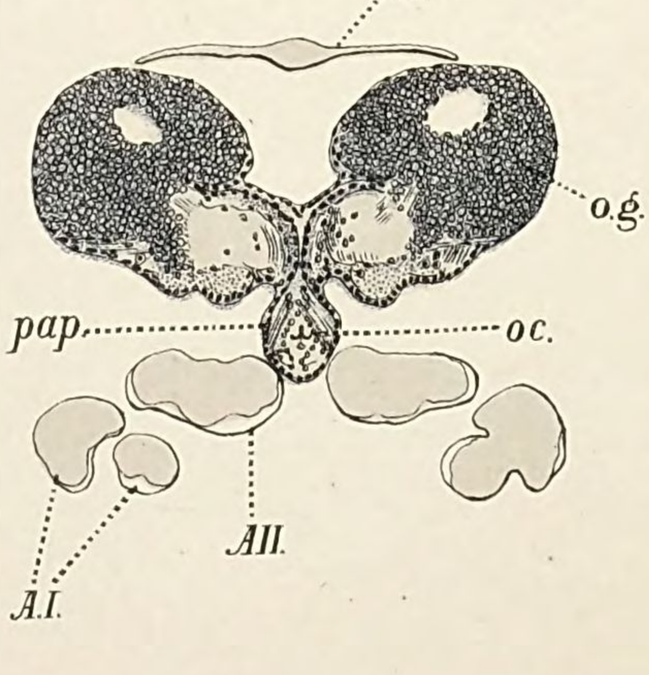
208.



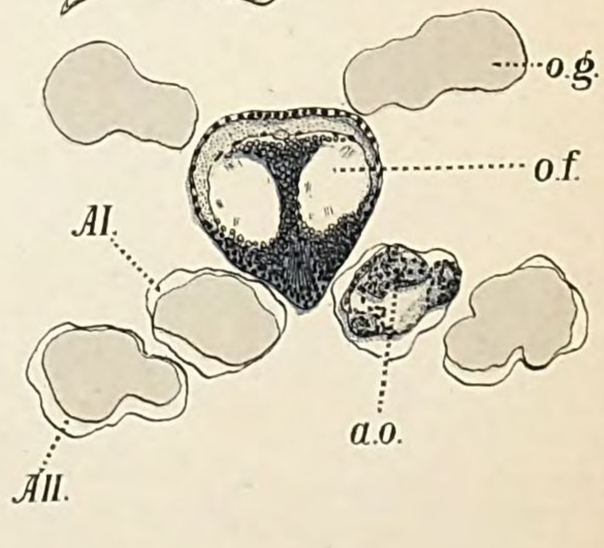
209.



210.



211.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York

ALPHEUS

PLATE LV.

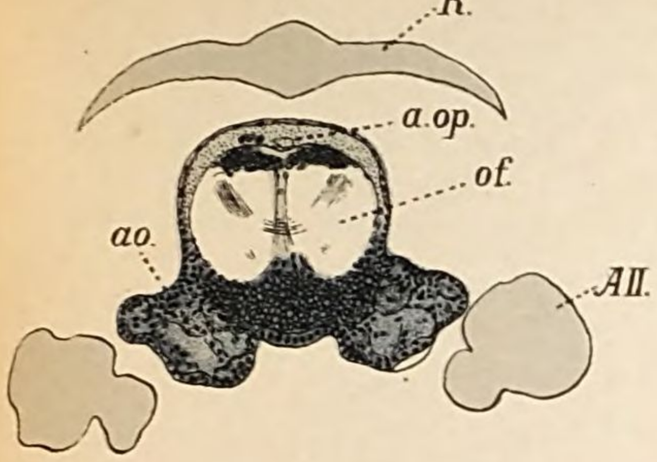
(Stage XII.)

FIGS. 212–223. Transverse serial sections of the first larva of *Alpheus saulcyi* from the same individual as Figs. 209–211, excepting Figs. 222, 223. ×73.

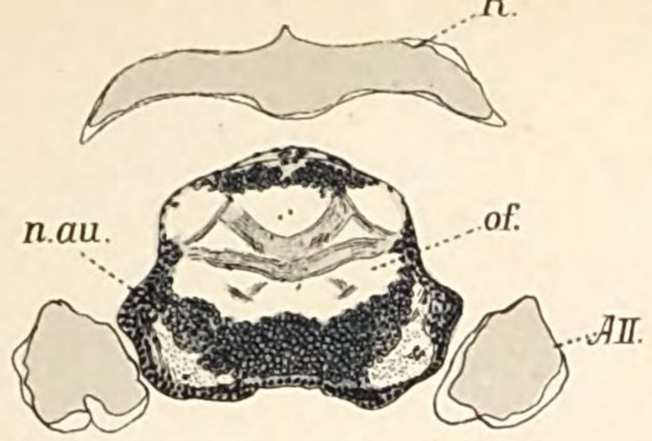
REFERENCE LETTERS.

A. II, second antenna.
ad. m., adductor of mandible.
ag., green gland.
af., antennular fiber-mass of brain.
ao., ear.
a. op., ophthalmic artery.
Bg., branchiostegite.
B. gl., gland-like body.
B. S., blood sinus.
fg., foregut.
fo., fiber-mass continued into œsophageal commissure.
gf., antennal fiber-mass.
gs., lateral pouch of masticatory stomach.
Lb., labrum.
lf., lateral fiber-mass of brain.
Md., mandible.
Mg., midgut.
Mg^{1}., anterior lobe of midgut.
Mg^{2}., lateral lobe of midgut.
Mp., septum between anterior lobes of midgut.
M. S., masticatory stomach.
Mts., metastoma.
Mx. I, first maxilla.
Mxpd. I, first maxilliped.
n. ag., antennal nerve.
n. an., antennular nerve.
oc., *ocm.*, œsophageal commissure.
of., anterior fiber-mass and transverse commissure of brain.
p. V., pyloric valve of masticatory stomach.
st. s., sternal sinus.

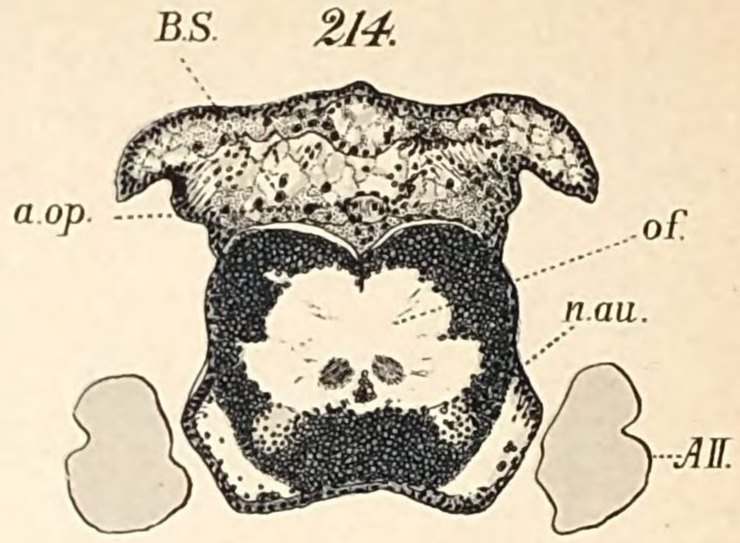
212.



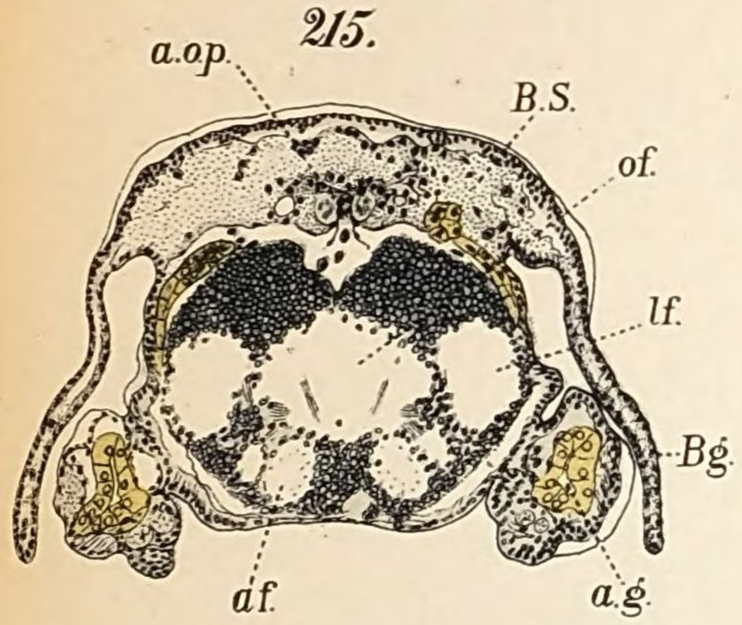
213.



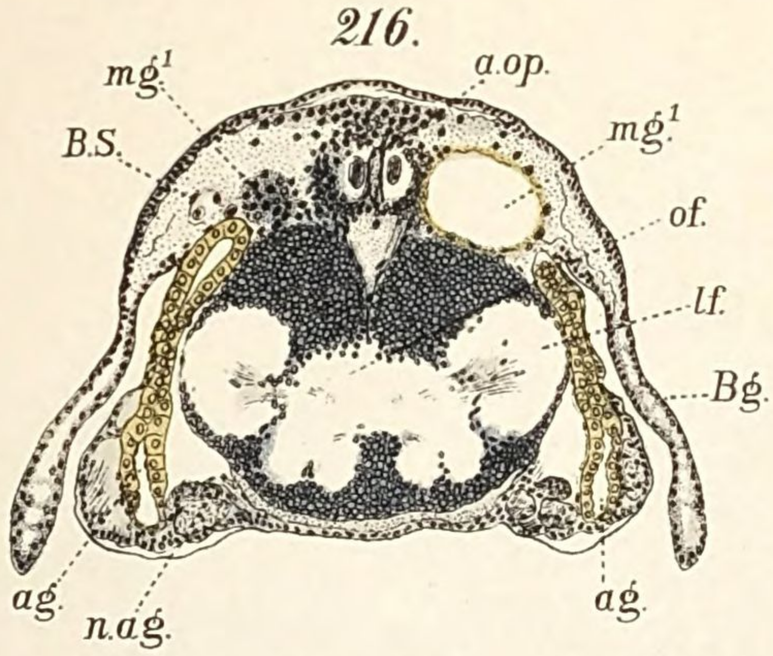
214.



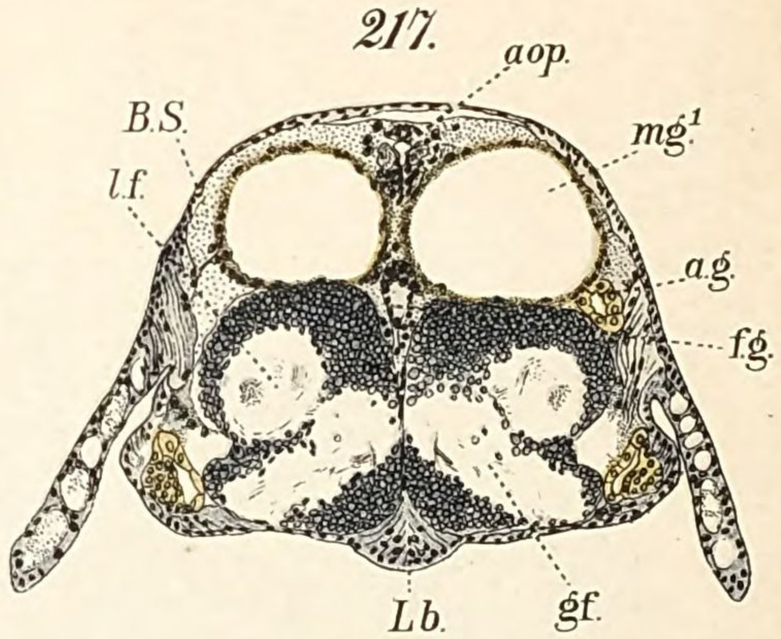
215.



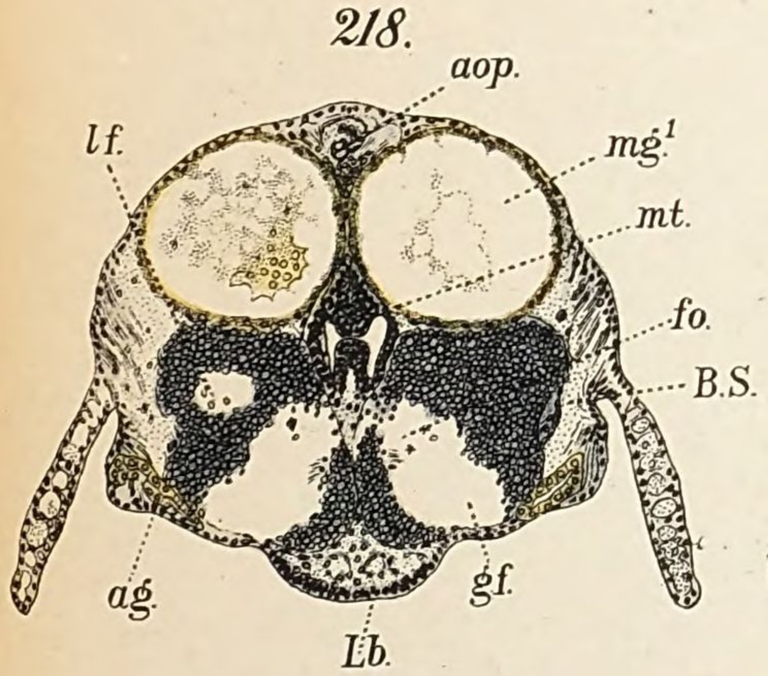
216.



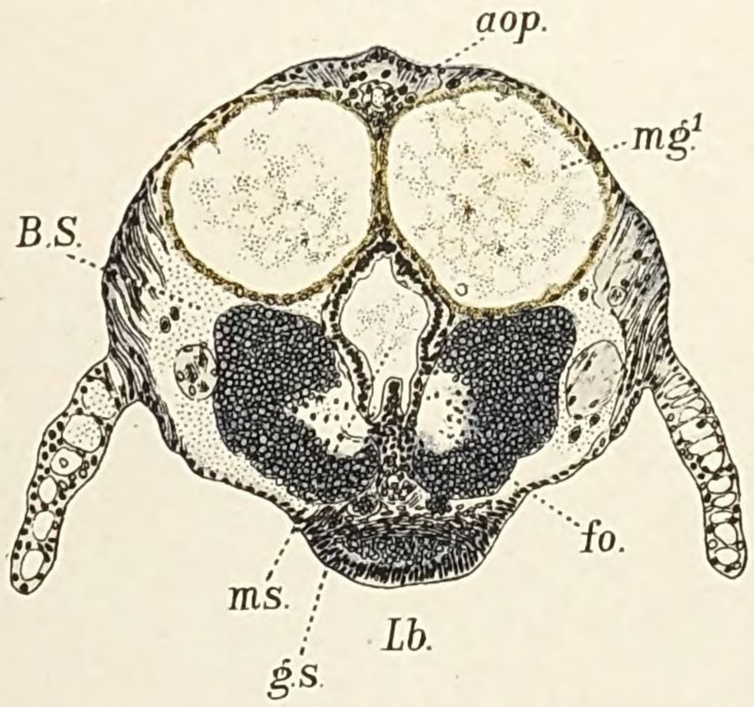
217.



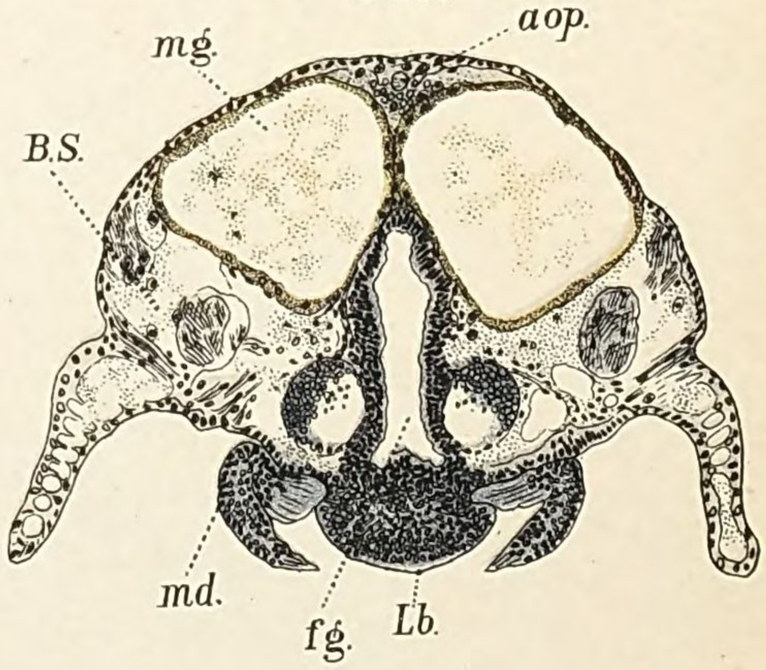
218.



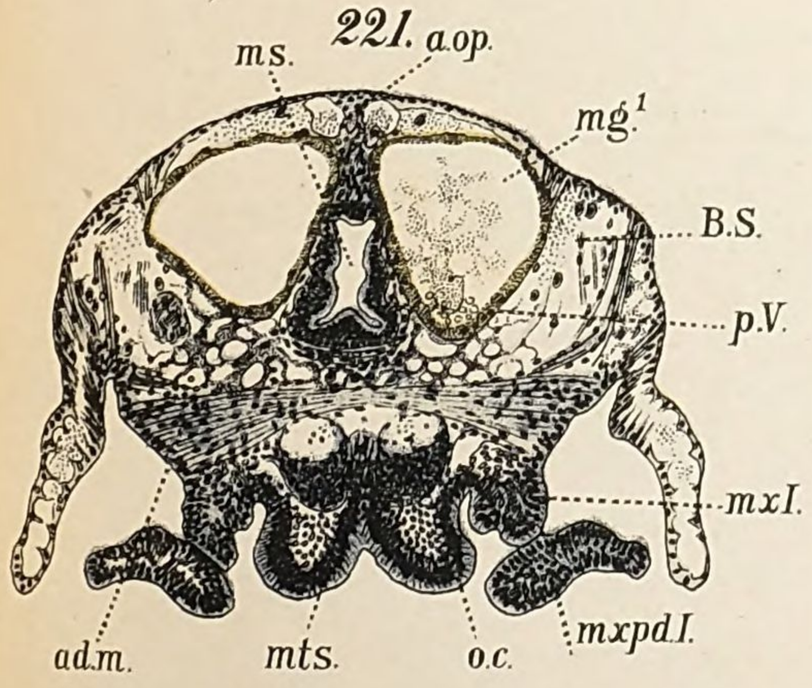
219.



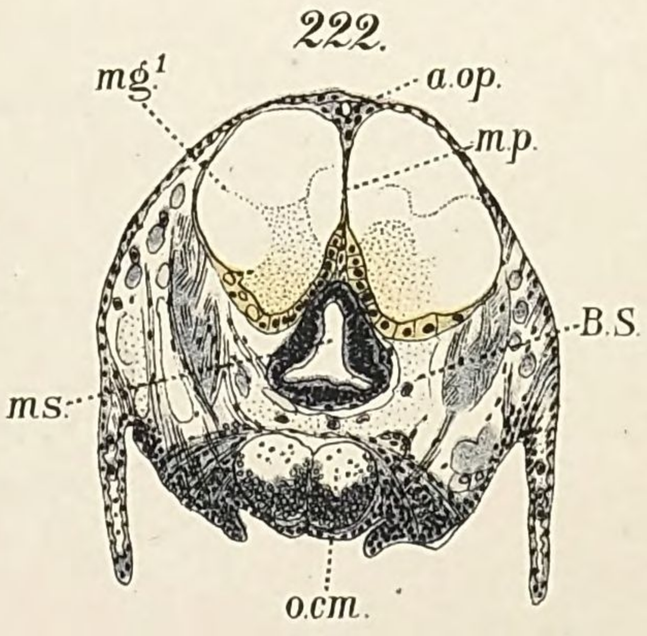
220.



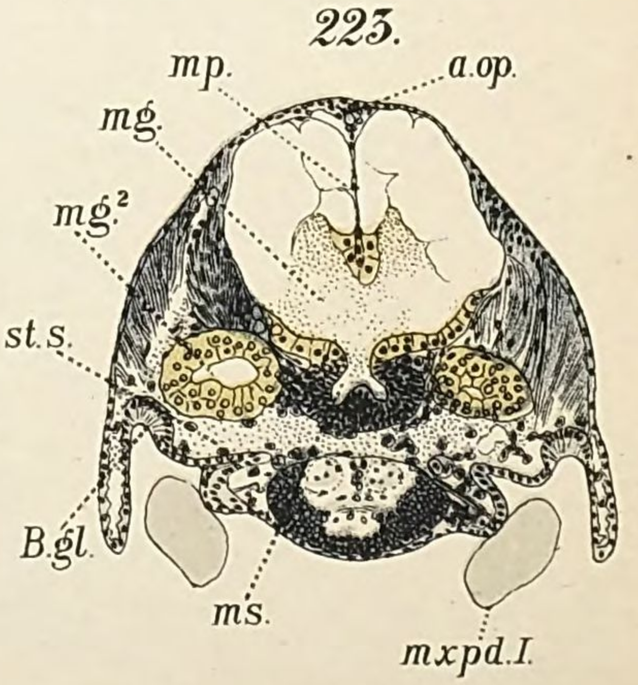
221.



222.



223.



F. H. Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

FIRST LARVA OF ALPHEUS SAULCYI.

PLATE LVI.

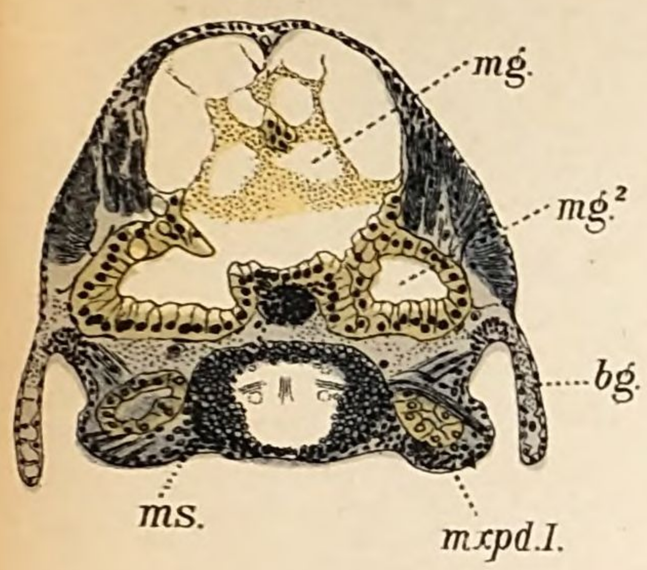
(Stage XII.)

FIGS. 224-235. Serial transverse sections through the first larva, continued from Plate LV. ×73.

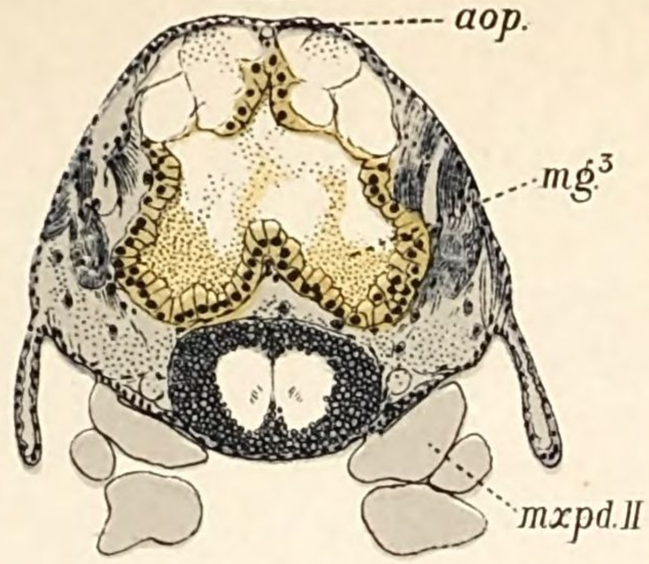
REFERENCE LETTERS.

Ab. V, fifth abdominal appendage.
a. i. a., inferior abdominal aorta.
a. op., ophthalmic artery.
a. s. a., superior abdominal artery.
bg., branchiostegite.
br., branchia of ambulatory appendage.
B. S., blood sinus.
gg. $^{1-3}$, middle, ventral, and dorsal lobules of posterior lobe of midgut.
H., heart.
hg., hindgut.
hy., hypodermis.
lc. th.-ab., longitudinal commissures uniting last thoracic with first abdominal ganglia.
Mg., midgut.
Mg. ^{2}, lateral lobe of midgut.
Mg. ^{3}, posterior lobe of midgut.
Ms., masticatory stomach.
Mu. e., extensor muscles of abdomen.
Mu. f., flexor muscles of abdomen.
Mxpd. I–III, first to third maxillipeds.
pleu., pleuron.
ps., pericardial sinus.
Th. I–V, first to fifth ambulatory limb.

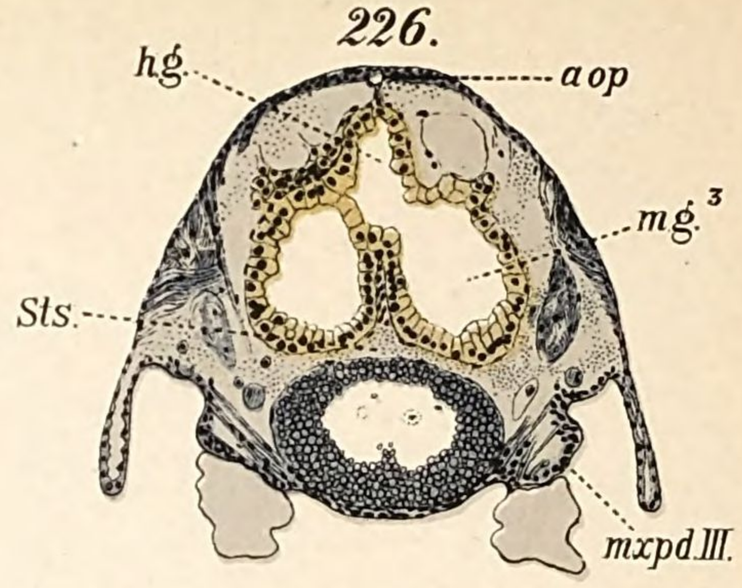
224.



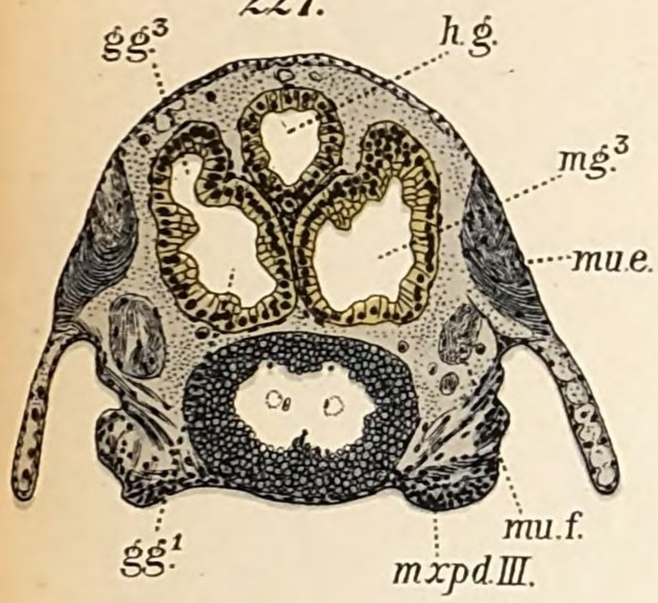
225.



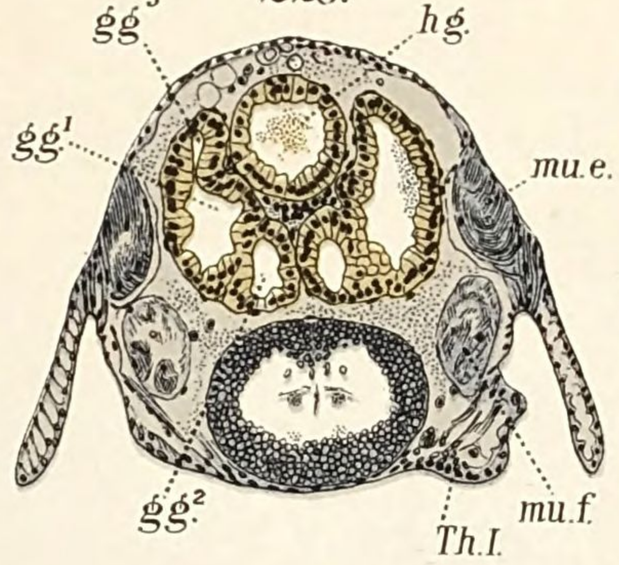
226.



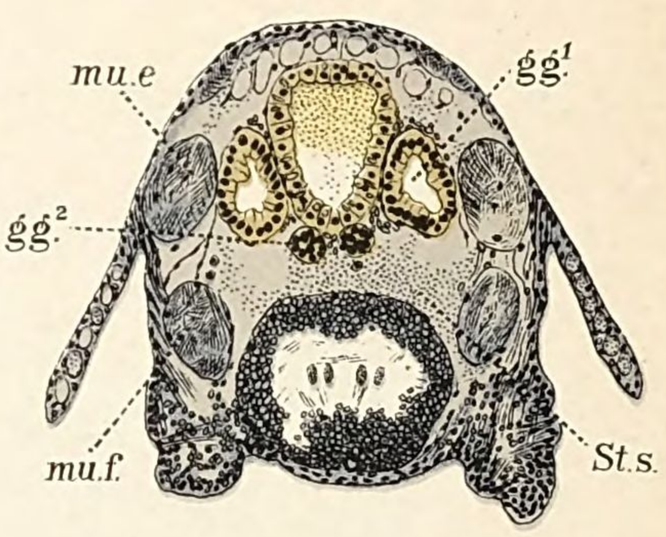
227.



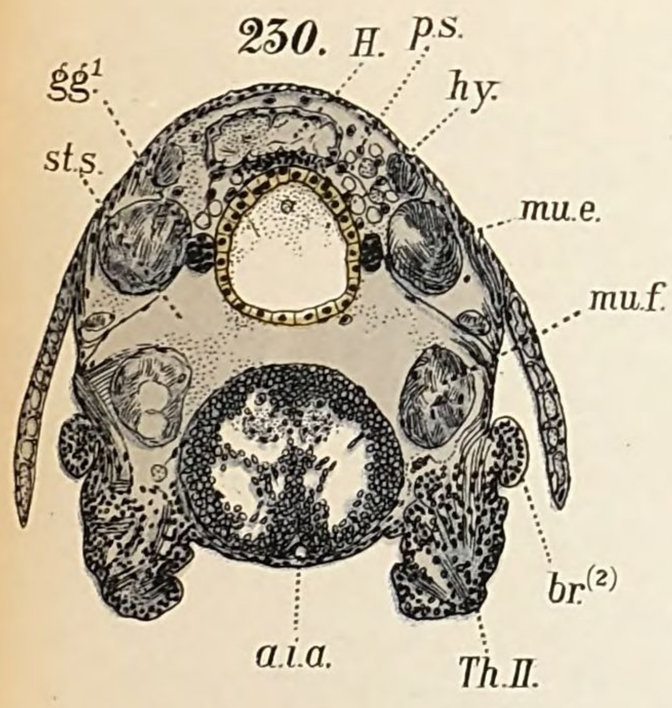
228.



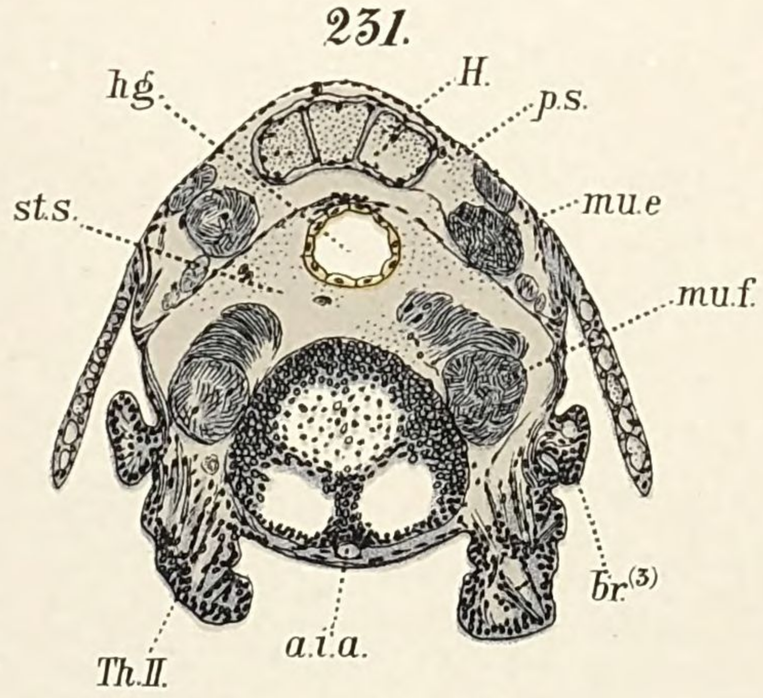
229.



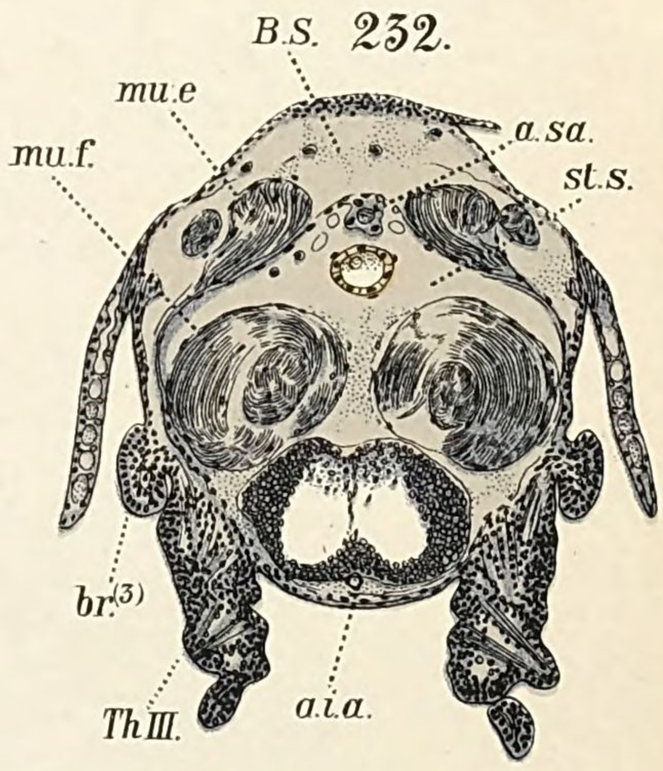
230.



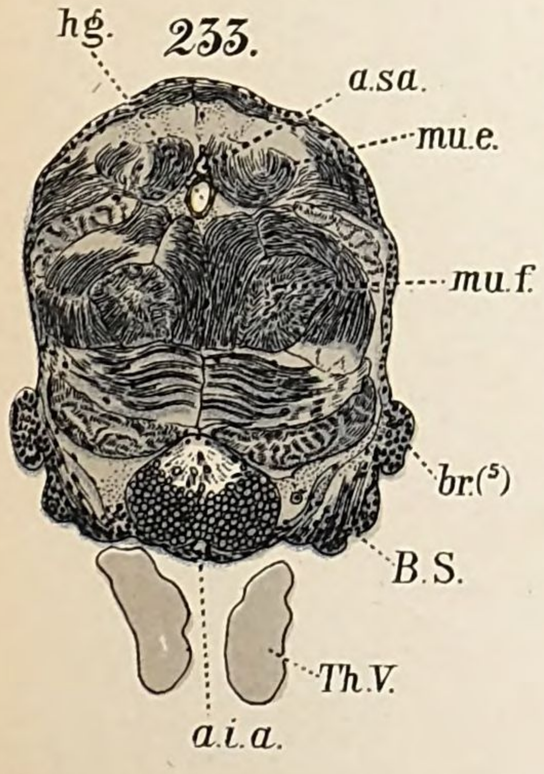
231.



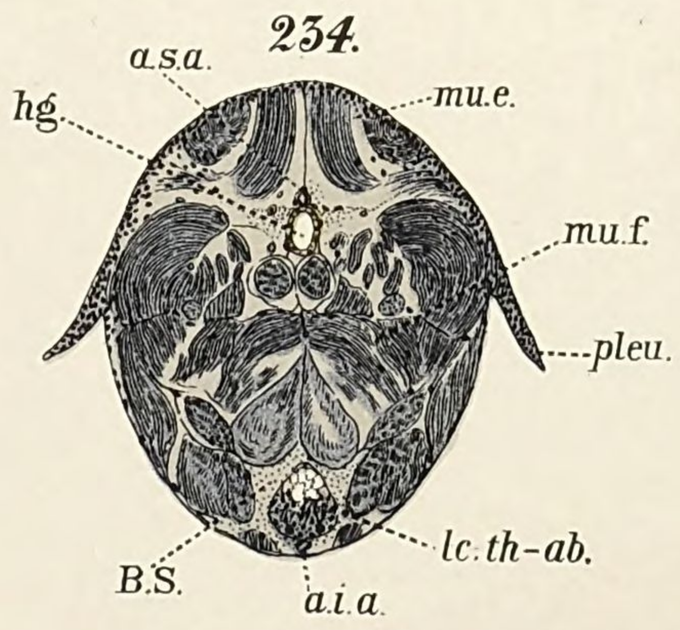
B.S. 232.



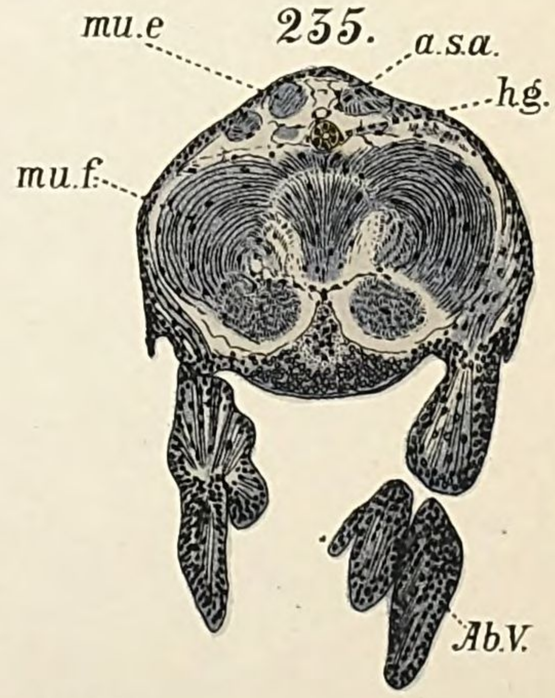
hg. 233.



234.



mu.e 235.



F.H.Herrick, del.

Sackett & Wilhelms Lithographing Co. New York.

FIRST LARVA OF ALPHEUS SAULCYI.

Plate LVII.

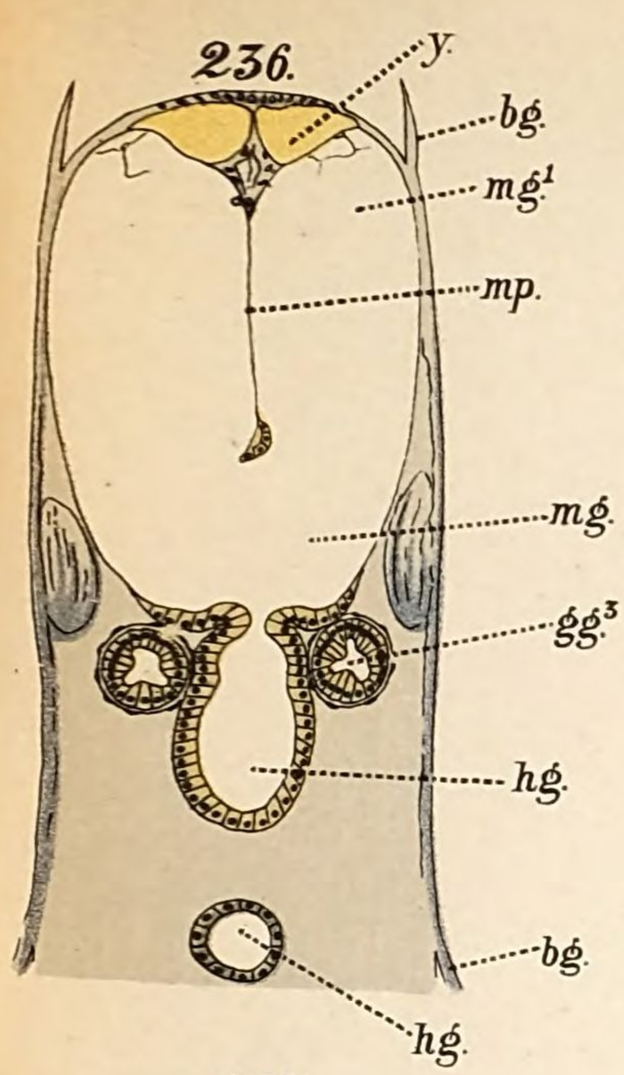
(Stage XII.)

Figs. 236–245. Horizontal sections of first larva, illustrating further the anatomy of the alimentary tract and the nervous system. ×57.

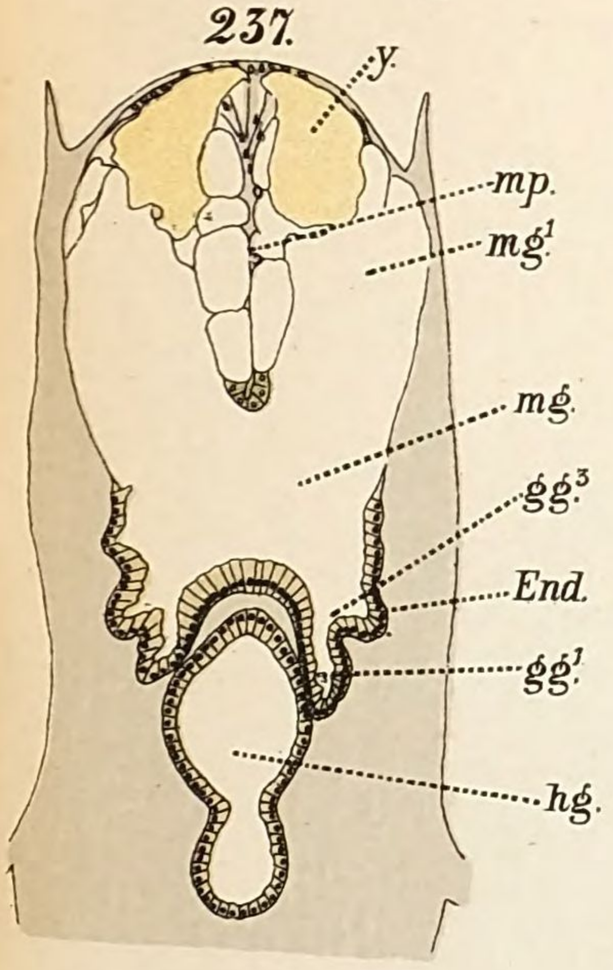
REFERENCE LETTERS.

A. I, II, first and second antenna.
ag., green gland.
af., antennular fiber-mass.
ao., ear.
bg., branchiostegite.
End., endoderm.
fg., foregut.
fo., fiber-substance of œsophageal commissure.
gf., fiber-mass of second antennæ.
gg. $^{1-3}$, middle, ventral, and dorsal divisions of posterior lobe of midgut.
hg., hindgut.
lf., lateral fiber-mass of brain.
Md., mandible.
Mg., midgut.
Mg.^{1}, lateral lobe of midgut.
Mp., partition between anterior lobes of midgut.
Mts., metastoma.
Mx. I, II, first and second maxillæ.
Mxpd. I–III, first to third maxillipeds.
n. an., antennular nerve.
n. c., ventral nerve-cord.
of., anterior fiber-mass of brain.
og., optic ganglion.
Ret., retina.
Th. I–V, first to fifth ambulatory limbs.
y., yolk.

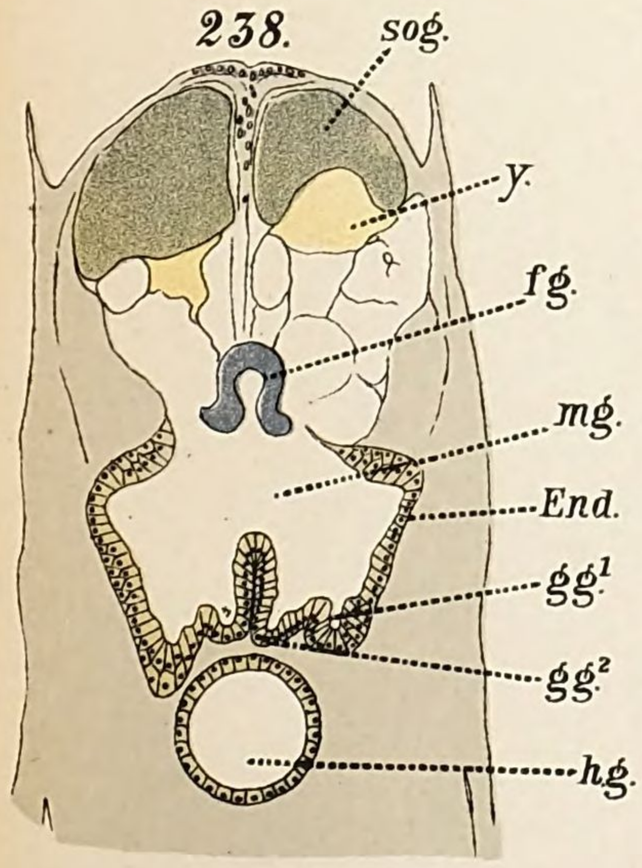
236.



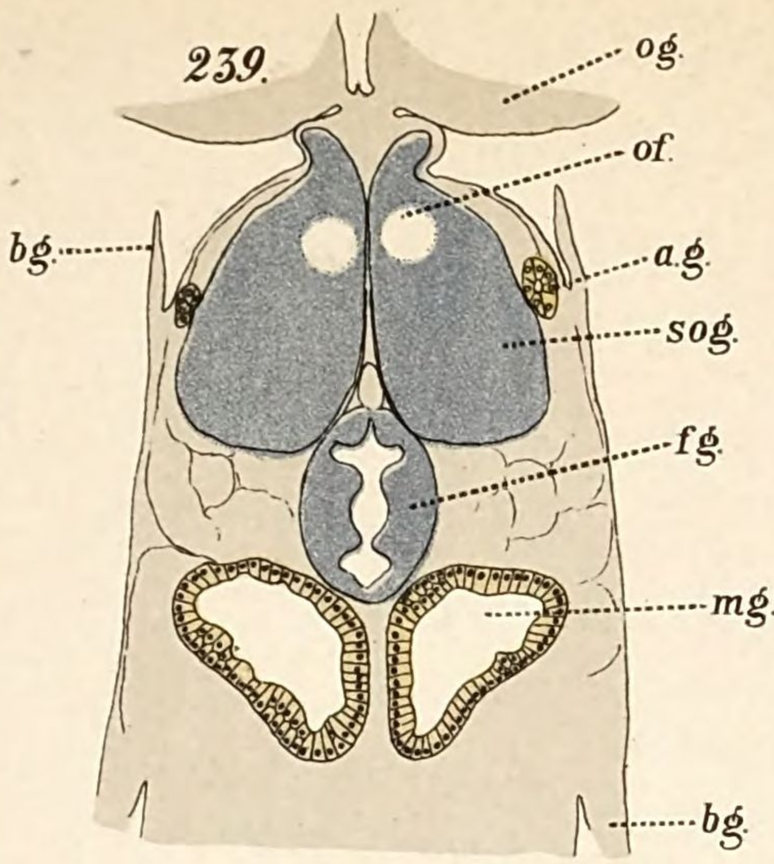
237.



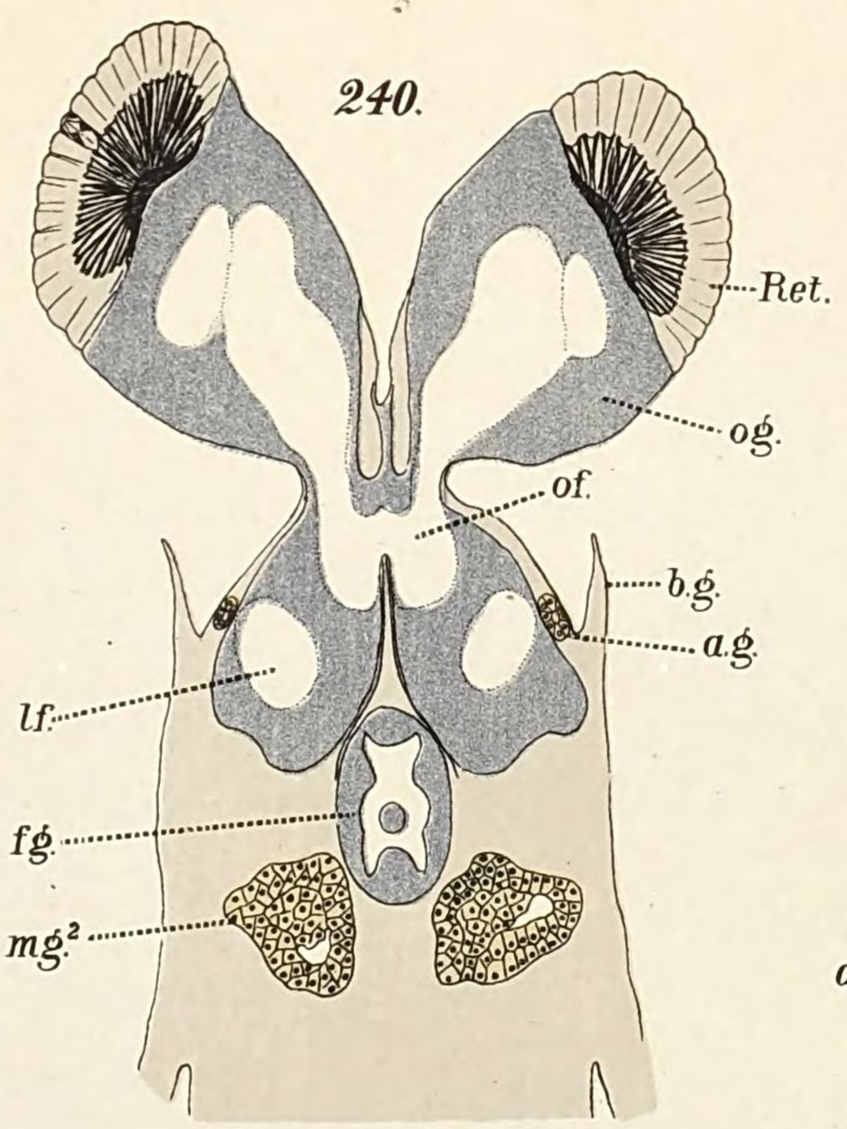
238.



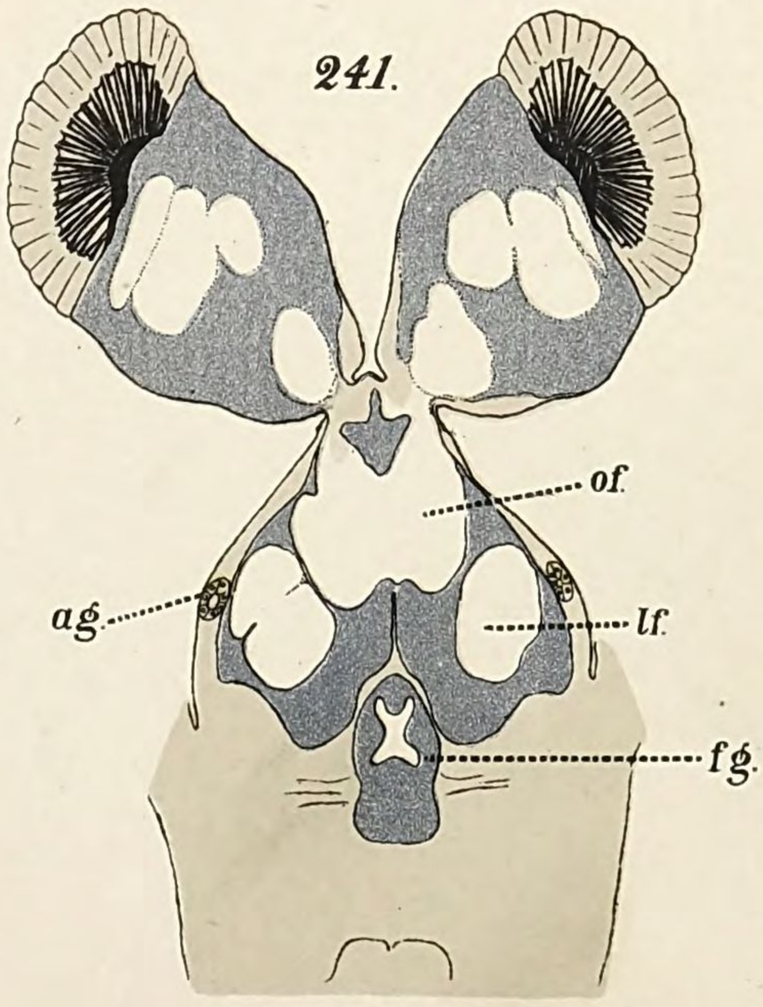
239.



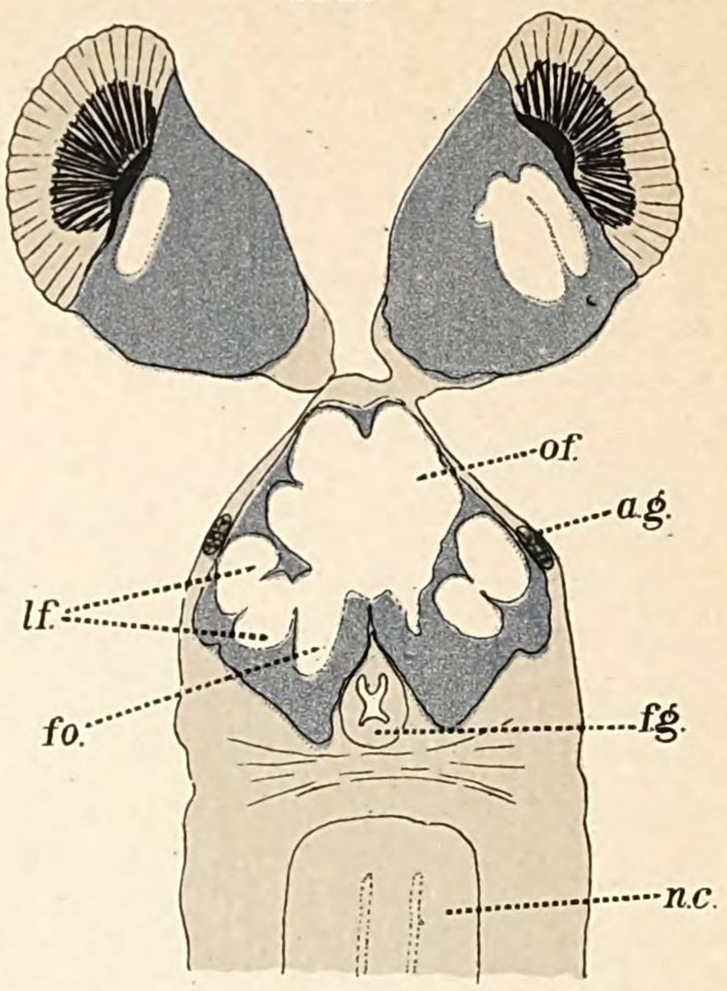
240.



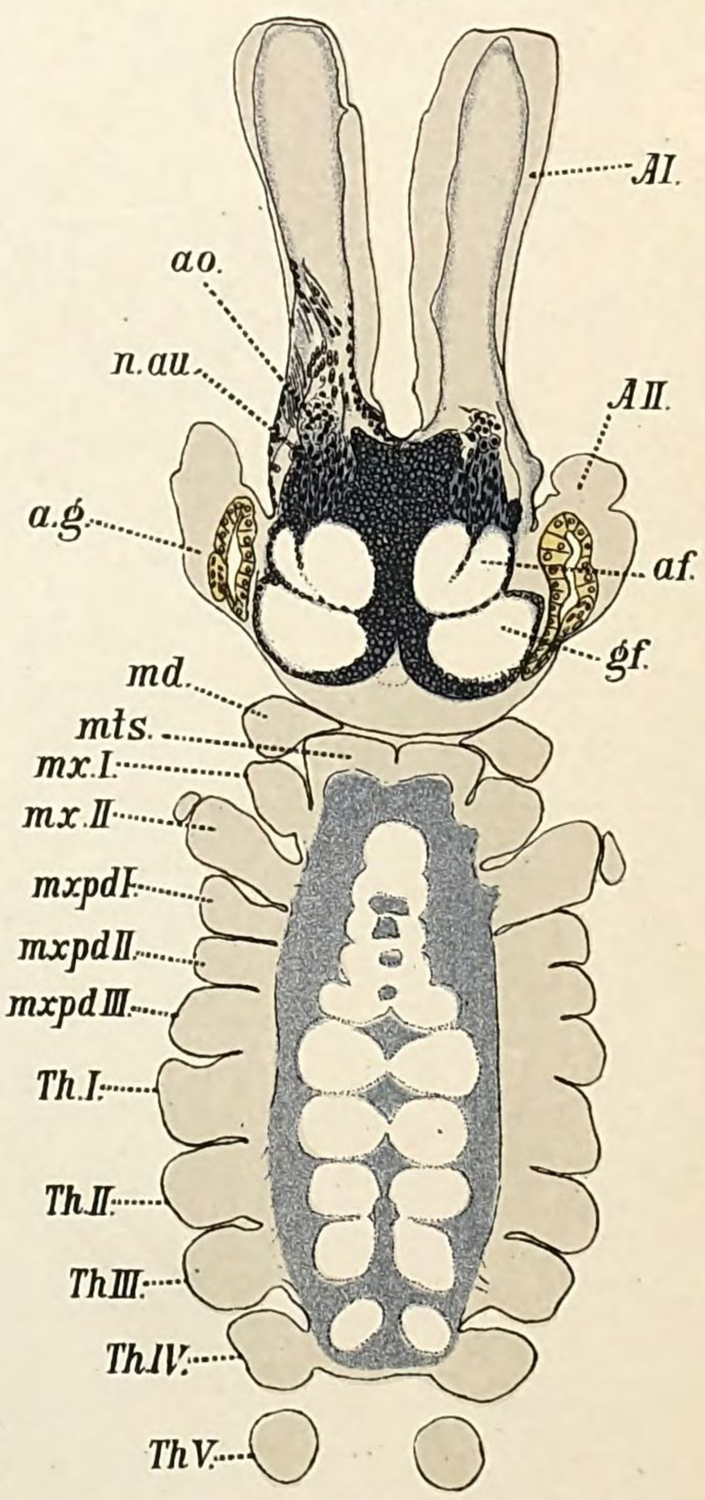
241.



242.



243.



F. H. Herrick, del.

FIRST LARVA OF ALPHEUS SAULCYI.

Sackett & Wilhelms Lithographing Co. New York.

NATIONAL ACADEMY OF SCIENCES.

VOL. V.

FIFTH MEMOIR.

ON THE APPLICATION OF INTERFERENCE METHODS TO ASTRONOMICAL MEASUREMENTS.

ON THE APPLICATION OF INTERFERENCE METHODS TO ASTRONOMICAL MEASUREMENTS.

ALBERT A. MICHELSON.

In a recent paper on "Measurement by Light Waves"* it was shown that the limitation of the effective portions of an objective to the extreme ends of a diameter converted the instrument into a refractometer, and, though definition and resolution are thereby sacrificed, the accuracy may be increased ten to fifty fold.

The simplest way of effecting this in the case of a telescope is to provide the cap of the objective with two slits, adjustable in width and distance apart. If such a combination be focused on a star, then, instead of an image of the star, there will be a series of colored interference bands, with white center, the bands being arranged at equal distances apart and parallel to the two slits. The position of the central white fringe can be marked from ten to fifty times as accurately as can the center of the telescopic image of the star.

One of the most promising applications of the method is the measurement of the angular magnitudes of small sources of light. This may be accomplished by taking advantage of the well known principle that in order to obtain clear interference bands from two pencils diverging from the same source (width a) at an angle β, it is necessary that either β or a be very small.

Thus, in Fig. 1 let us take—

$a = ee_1$ = width of the source,

D = distance of source from objective,

$b = SS_1$ = distance between the slits.

Also put $S_1P = \triangle$, $\frac{a}{D} = \alpha$, $\frac{b}{D} = \beta$.

Then the usual statement is that the interference fringes vanish

$$\text{when } Se_1 - Se = \tfrac{1}{2}\beta a = \tfrac{1}{2}b\alpha = \tfrac{1}{2}\lambda, \text{ or when } \alpha = \frac{\lambda}{b}.$$

But $\frac{\lambda}{b}$ is the "limit of resolution" of the telescope of aperture b, and if this be denoted by α_0 we have $\alpha = \alpha_0$. Or, in words, the fringes disappear when the source subtends an angle which can just be resolved by the telescope.

The experiment was first tried with an objective of 45^{mm} effective diameter (distance between the slits) at a distance of 10 meters from an adjustable slits, which served as the source. It was found that the first indication of indistinctness occurred when a was 0.08^{mm} wide, and at 0.14^{mm} the fringes almost vanished. *But on continuing to widen the slit they again became clearly visible, to disappear and reappear at regular intervals.*

---

* American Journal of Science, Vol. XXXIX, February, 1890.

Now, though it might with truth be urged that the observations of the indefinite vanishing of interference fringes depends so much on attendant circumstances, and especially on the condition of the observer, that it can scarcely be called a precise measurement, yet the statement applies no longer when the disappearance depends on well marked minima of distinctness, and, as will appear below, it is possible to measure with accuracy by the observation of these minima the width of a source of light which in a telescope can with difficulty be ascertained to have an appreciable size. The theory of these successive appearances and disappearances is as follows:

Returning to Fig. 1, let x be the distance of any element of the source from the axis of the telescope, dx the width of the element, and $y=\varphi(x)$ the length. Then the difference in the two paths xS and xS$_1$P terminating at the wave front P, which makes an angle ν with the plane perpendicular to the axis of the telescope, will be $\beta x-\nu b$, and the resulting intensity in the direction γ for the whole source will therefore be

$$I=\int \varphi(x)\left[1+\cos\frac{2\pi}{\lambda}\left(\beta x-\gamma b\right)\right]dx \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

CASE I.—*Uniformly Illuminated Slit.*

If the source be a slit whose center is in the axis and whose length is parallel to the slits SS$_1$ and whose width is a, then

$$I=a+\frac{\lambda}{\pi\beta}\sin\frac{\pi\beta}{\lambda}a\cos\frac{2\pi\gamma}{\lambda}b \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

If I_1 be the intensity at the center of a bright fringe and I_2 that at the center of a dark fringe, then the visibility of the fringes may be expressed by

$$V=\frac{I_1-I_2}{I_1+I_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

But

$$I_1=a+\frac{\lambda}{\pi\beta}\sin\frac{\pi\beta}{\lambda}a$$

$$I_2=a-\frac{\lambda}{\pi\beta}\sin\frac{\pi\beta}{\lambda}a$$

$$\therefore\ V=\frac{\sin\frac{\pi\beta}{\lambda}a}{\frac{\pi\beta}{\lambda}a}$$

or, finally,

$$V=\frac{\sin\pi\frac{\alpha}{\alpha_0}}{\pi\frac{\alpha}{\alpha_0}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Hence the fringes will disappear whenever α is a multiple of α_0. They will be clearest when

$$\alpha=\frac{\alpha_0}{\pi}\operatorname{tang}\pi\frac{\alpha}{\alpha_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

The curve of visibility will be of the form shown in Fig. 2.

The successive values of the maxima (disregarding signs), calculated from the above equation, are

$$V_1=+1.000$$
$$V_2=-\ .210$$
$$V_3=+\ .130$$
$$V_4=-\ .091$$

The negative values mean that during the corresponding period the fringes are reversed.*

As the expression for V contains λ, the wave-length of the light employed, the fringes can disappear for that color (and the complementary one) only, and as this will be most decided for the brightest color in the spectrum, the yellow or greenish yellow (and therefore also for violet), there will be a residue of red and blue-green mixed with much white light. Both of these deductions have been fully verified by experiment.

Table I shows well the accordance between theory and observation. Under S is given the nature of the light used; S denotes sunlight; C, calcium light; R, red light.

The other quantities given in the table are—

λ=approximate wave length in thousandths of a millimeter.

a=width of slit by direct measurement.

d=distance to telescope.

b=distance between centers of slits.

f=factor depending on the order of the observed disappearance.

α=angle deduced from the observations.

$\alpha_1 = \frac{a}{d} \times 206265''$.

e=error in seconds.

o=error in per cent.

It may be noted that under the observations marked R no less than eight successive disappearances were noted, the average error of each being less than 2 per cent.

TABLE I.

S	λ	a	d	b	f	α	α_1	e	o
						//	//	//	
S	.550	.230	20,800	50.15	1.00	2.26	2.38	—0.12	— 5
S	.550	.490	20,800	23.35	1.00	4.86	4.85	+ .01	0
S	.550	.740	20,800	15.45	1.00	7.33	7.33	.00	0
C	.570	.197	20,340	65.75	1.00	1.78	1.99	— .21	—10
C	.570	.365	20,340	65.75	2.00	3.57	3.69	— .12	— 3
C	.570	.547	20,340	65.75	3.00	5.35	5.53	— .18	— 3
C	.570	.723	20,340	65.75	4.00	7.14	7.31	— .17	— 2
C	.570	.900	20,340	65.75	5.00	8.92	9.11	— .19	— 2
C	.570	.238	20,340	53.75	1.00	2.18	2.41	— .23	—10
C	.570	.442	20,340	53.75	2.00	4.36	4.47	— .11	— 3
C	.570	.650	20,340	53.75	3.00	6.55	6.58	— .03	0
C	.570	.865	20,340	53.75	4.00	8.73	8.75	— .02	0
C	.570	1.105	20,340	53.75	5.00	10.91	11.18	— .27	— 3
C	.570	.277	20,340	40.75	1.00	2.88	2.80	+ .08	+ 3
C	.570	.567	20,340	40.75	2.00	5.76	5.74	+ .02	0
C	.570	.858	20,240	40.75	3.00	8.64	8.68	— .02	0
C	.570	1.150	20,240	40.75	4.00	11.52	11.64	— .12	— 1
C	.570	1.412	20,340	40.75	5.00	14.40	14.28	+ .12	+ 1
C	.570	.388	20,340	31.15	1.00	3.77	3.93	— .16	— 4
C	.570	.757	20,340	31.15	2.00	7.54	7.66	— .12	— 2
C	.570	1.16	20,340	31.15	3.00	11.31	11.73	— .42	— 4
C	.570	1.532	20,340	31.15	4.00	15.08	15.40	— .32	— 2
C	.570	1.902	20,340	31.15	5.00	18.85	19.25	— .40	— 2
R	.623	.298	20,340	44.75	1.00	2.86	3.02	— .16	— 5
R	.623	.573	20,340	44.75	2.00	5.73	5.80	— .07	— 1
R	.623	.852	20,340	44.75	3.00	8.65	8.62	+ .03	0
R	.623	1.108	20,340	44.75	4.00	11.46	11.21	+ .25	+ 2
R	.623	1.415	20,340	44.75	5.00	14.32	14.32	.00	0
R	.623	1.672	20,340	44.75	6.00	17.18	16.92	+ .26	+ 2
R	.623	1.945	20,340	44.75	7.00	20.05	19.69	+ .36	+ 2
R	.623	2.223	20,340	44.75	8.00	22.91	22.49	+ .42	+ 2

* Probably the expression for V should be $\left(\frac{I_1 - I_2}{I_1 + I_2}\right)^2$ but this will not affect the position of the points for which V=0.

CASE II.—*Uniformly Illuminated Disk.*

If the source be a uniformly illuminated disk of radius r the expression to be integrated is

$$I=4\int_0^r \sqrt{r^2-x^2}\left[1+\cos\frac{2\pi}{\lambda}\left(\beta x-\gamma b\right)\right]dx. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Putting α=angular diameter.

$$\left(\text{Then } \frac{\beta}{\lambda}=\frac{\alpha}{\alpha_0}\frac{1}{r}.\right) \qquad \text{Write } \frac{x}{r}=w, \text{ and } \pi\frac{\alpha}{\alpha_0}=n.$$

Then, omitting the phase constant γb, this reduces to the form

$$I=\frac{\pi}{4}\left\{1\pm\frac{4}{\pi}\int_0^1 \sqrt{1-w^2}\cos nw\,dw.\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

in which the integral is positive for the maxima and negative for the minima.

$$\text{Putting } \int_0^1 \sqrt{1-w^2}\cos nw\,dw=A, \text{ we have for V.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$V=A. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Tables for A are given in Airy's "Undulatory Theory," and give the results expressed in the curve shown in Fig. 3.

The values of $\frac{\alpha}{\alpha_0}$, for which the fringes disappear, are 1.22, 2.24, 3.26, 4.26, etc., and the values of the successive (positive or negative) maxima are:

$$V_1=\ \ 1.000$$
$$V_2=-0.130$$
$$V_3=+0.065$$
$$V_4=-0.040$$

Here too the theory is remarkably well confirmed by experiment. This is shown by Table II, in which the letters have the same meaning as before, save that a is now the diameter of the circular aperture.

TABLE II.

S	λ	a	d	b	f	α	α_1	e	v
						//	//	//	
S	.550	.701	20,800	20.15	1.22	6.85	6.94	0.09	−1.
C	.570	.200	20,340	77.71	1.22	1.85	2.02	− .17	−8.
C	.570	.271	20,340	51.95	1.22	2.76	2.73	+ .03	+1
C	.570	.445	20,349	32.50	1.22	4.41	4.50	− .09	−2
C	.570	.445	20,340	52.45	2.24	4.52	4.50	− .02	0
C	.570	.445	20,340	81.45	3.26	4.60	4.50	+ .10	+2.
C	.570	.701	20,340	20.00	1.22	7.17	7.09	+ .08	+1
C	.570	.701	20,340	34.85	2.24	7.55	7.09	+ .46	+6.
C	.570	.701	20,340	52.99	3.26	7.14	7.09	+ .05	+1
C	.570	1.000	20,340	25.65	2.24	10.20	10.12	+ .18	+2
C	.570	1.000	20,340	14.65	1.22	9.77	10.12	− .35	−4
C	.570	1.000	20,340	27.35	2.24	9.63	10.12	− .49	−5
C	.570	1.000	20,340	38.55	3.26	9.87	10.12	− .25	−2.
C	.570	1.230	20,340	21.08	2.24	12.47	12.44	+ .03	0
C	.570	1.230	20,340	30.45	3.26	12.58	12.44	+ .14	+1
C	.570	1.230	20,340	11.15	1.22	12.85	12.44	+ .41	+3.
C	.570	1.230	20,340	21.45	1.24	12.23	12.44	− .21	−2.
C	.570	1.230	20,340	31.15	3.26	12.25	12.44	− .19	−2
C	.570	1.230	20,340	39.95	4.26	12.49	12.44	+ .05	0
C	.570	1.465	20,340	17.42	2.24	14.92	14.82	+ .10	+1
C	.570	1.465	20,340	25.99	3.26	14.70	14.82	− .12	−1
C	.570	1.690	20,340	15.14	2.24	17.36	17.10	+ .26	+2
C	.570	1.690	20,340	23.40	3.26	16.36	17.10	− .74	−4
R	.623	0.445	20,340	35.15	1.22	4.45	4.50	− .05	−1

The curve V=A (Fig. 3) shows that the maxima are considerably smaller than in the case of the slit, and accordingly the disappearances are not quite so sharp; but in one case it was possible to note four of them, and in this case also the average error was less than two per cent.

CASE III.—*Illumination not uniform.*

On applying the preceding formulæ to observations on images of the sun's disk, the angles obtained were all too small by about 10 per cent, the cause of the discrepancy being the want of uniformity of illumination.

The curve (Fig. 4) represents the intensity at any point of the sun's disk as a function of its distance from the center $i=f(x^2+y^2)^{\frac{1}{2}}$. The ordinates are taken from Vogel's Table.*

From this curve we obtain that shown in Fig. 5 by integrating the expression

$$\int_0^{\sqrt{r^2-x^2}} f(x^2+y^2)^{\frac{1}{2}}dy=\varphi(x) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

The value of $\varphi(x)$ substituted in (1) gives on integration the value of the intensity of the maxima and minima in the form $I=1\pm B$, whence finally we get for the visibility of the fringes

$$V=B. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The values of B (found from equation 10) are plotted in the curve shown in Fig. (6).†

The fringes disappear at the points for which $\frac{\alpha}{\alpha_0}$ is 1.33, 2.38, etc., and the values of the successive (positive and negative) maxima are

$$V_1=+1.000$$
$$V_2=-0.100$$
$$V_3=+0.042$$
$$V_4=-0.028$$

On applying these results to the observations the accordance is very satisfactory, as appears from the following table:

TABLE III.

S	λ	*a*	*d*	*b*	*f*	α	α_1	*e*	*v*
						//	//	//	
S	.550	.231	27,800	84.75	1.33	1.74	1.71	+0.03	+2
S	.550	.377	27,800	55.25	1.33	2.72	2.79	— .07	—2.
S	.550	.933	27,800	22.65	1.33	6.66	6.90	— .24	—3
S	.550	.231	21,200	66.15	1.33	2.27	2.24	+ .03	+1.
S	.550	.377	21,200	41.75	1.33	3.59	3.66	— .07	—2
S	.550	.933	21,200	16.65	1.33	9.04	9.05	— .01	0

CASE IV.—*Double Source.*

Suppose next that there are two equal symmetrical sources of light whose centers are at *C* and C_1 (Fig. 7).

---

* Young on "The Sun."

† The curves corresponding to Cases I, II, and III are for convenience of comparison given together in Plate (I).

Let $OC=CB=DC_1=C_1E=r$
Let $CC_1=2s$. $OP=x$. $PQ=y$

Then the intensity of the interference fringes will be

$$I=\int y\left(1+\cos\frac{2\pi\Delta}{\lambda}\right)dx \text{ . . . . as in (1)}$$

Integrating from O to B and from D to E, we have

$$I=\int_0^{2r} y_1\left(1+\cos\frac{2\pi\Delta}{\lambda}\right)dx+\int_{2s}^{2s+2r} y_2\left(1+\cos\frac{2\pi\Delta}{\lambda}\right)dx \quad \text{. . . . . (11)}$$

where $y_1=f(x-r)$ and $y_2=f[x-(2s+r)]$

and $\Delta=\beta x-\gamma b.$

In the first integral put $w_1=x-r.$
In the second integral put $w_2=[x-(2s+r)].$

Then we obtain

$$I=\int_{-r}^{+r} f(w_1)\left[1+\cos\frac{2\pi}{\lambda}(\beta w_1+\beta r-\gamma b)\right]dw_1$$

$$+\int_{-r}^{+r} f(w_2\left[1+\cos\frac{2\pi}{\lambda}(\beta w_2+\beta r-\gamma b+2\beta s)\right]dw_2$$

Expanding the first of these integrals we obtain

$$\int_{-r}^{+r} f(w_1)dw_1+\cos\frac{2\pi}{\lambda}(\beta r-\gamma b)\int_{-r}^{+r} f(w_1)\cos\frac{2\pi}{\lambda}\beta w_1 dw_1 -\sin\frac{2\pi}{\lambda}(\beta r-\gamma b)\int_{-r}^{+r} f(w_1)\sin\frac{2\pi}{\lambda}(\beta w_1)dw_1)$$

in which the first term is half the area of the aperture and the last term (since $\sin\frac{2\pi}{\lambda}\beta w_1$ is an uneven function) is 0. The same is also true of the expansion of the second integral. If then we put

$$\int_{-r}^{+r} f(w)\,dw=\tfrac{1}{2}Q$$

$$\int_{-r}^{+r} f(w)\cos\frac{2\pi}{\lambda}\beta w\,dw=\tfrac{1}{2}QA$$

equation (12) becomes

$$I=Q+\tfrac{1}{2}QA\cos\frac{2\pi}{\lambda}(\beta r-\gamma b)+\tfrac{1}{2}QA\cos\frac{2\pi}{\lambda}(\beta r-\gamma\beta+2\beta s)$$

$$\text{or } I=Q+QA\left[\cos\frac{2\pi}{\lambda}(\beta s+\beta r-\gamma b)\cos\frac{2\pi}{\lambda}\beta s\right] \quad \text{. . . . . (13)}$$

whence for the visibility

$$V=\frac{I_1-I_2}{I_1+I_2}=A\cos\frac{2\pi}{\lambda}\beta s$$

or finally

$$V=A\cos\pi\frac{\alpha}{\alpha_0} \quad \text{. . . . . (14)}$$

First. When the sources are two equal uniformly illuminated slits, of height $2h$.

$$f(w)=h \text{ and } Q=4rh.$$

Hence

$$A=\frac{1}{r}\int_0^r \cos\frac{2\pi\beta}{\lambda}w\,dw=\frac{\sin\frac{2\pi}{\lambda}\beta r}{\frac{2\pi}{\lambda}\beta r} \quad \text{. . . . . (15)}$$

Putting $\frac{2\pi}{\lambda}\beta r=\pi\frac{\alpha}{\alpha_0}$ and substituting for A in equation (14) we obtain

$$V=\frac{\sin\pi\frac{\alpha}{\alpha_0}}{\pi\frac{\alpha}{\alpha_0}}\cos\pi\frac{\alpha_1}{\alpha_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

Second. For the case of two equal uniformly illuminated circular apertures of radius r

$$f(w)=\sqrt{r^2-w^2} \text{ and } Q=\pi r^2$$

Hence

$$A=\frac{4}{\pi r^2}\int_0^r\sqrt{r^2-w^2}\cos\frac{2\pi}{\lambda}\beta w dw \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

Putting $\frac{w}{r}=z$ this reduces to the form already given for Airy's integral and the expression for the visibility of the fringes is

$$V=A_1\cos\pi\frac{\alpha}{\alpha_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

When the distance between the sources is more than five or six times the width, the periodicity of the second term alone is of importance, the term A_1 representing the amplitude of the variation.

The fringes vanish whenever $\alpha=\frac{2n-1}{2}\alpha_0$.

The general form of the visibility curve is given in Fig. 8.

If, on the other hand, the two sources coincide, the expression reduces to that previously found for a single circular source.

Table IV exhibits the results of observations made upon two circular apertures whose diameter is given under the column a_1 and whose distance between centers under a. It will be seen that the distance varies from 11 to 5 diameters, and that the average error of one observation (usually a single setting) is only $1\frac{1}{2}$ per cent.

TABLE IV.

S	λ	a_1	a	b	f	α	α_1	e	o
						//	//	//	
C	.560	.060	.693	25.1	1.50	6.90	6.80	+0.10	+2
C	.560	.060	.693	25.3	1.50	6.85	6.80	+ .05	+1
C	.560	.060	.693	25.7	1.50	6.75	6.80	— .05	—1
C	.560	.060	.693	25.7	1.50	6.75	6.80	— .05	—1
C	.560	.060	.666	26.6	1.50	6.53	6.58	— .05	—1
C	.560	.060	.666	26.7	1.50	6.50	6.58	— .08	—1
C	.560	.0 0	.519	34.4	1.50	5.00	4.99	+ .01	0
C	.560	.060	.465	12.9	.50	4.48	4.56	— .08	—2
C	.560	.0 0	.315	18.8	.50	3.07	3.09	— .02	—1
R	.623	.0 0	.693	27.8	1.50	6.93	6.80	+ .13	+2
R	.623	.060	.693	27.9	1.50	6.90	6.80	+ .10	+2
R	.623	.060	.666	29.5	1.50	6.53	6.58	— .05	—1
R	.623	.060	.66	29.4	1.50	6.57	6.58	— .01	0
S	.550	.117	.526	10.75	.50	5.27	5.18	+ .09	+2
S	.550	.117	.526	11.65	.50	4.86	5.03	— .17	—3
C	.560	.117	.526	10.85	.50	5.32	5.32	00	0
C	.560	.117	.525	33.24	1.50	5.21	5.32	— .11	—2
C	.560	.117	.526	55.80	2.50	5.18	5.32	— .14	—3
C	.560	.117	.526	80.15	3.50	5.04	5.32	— .18	—3
R	.623	.117	.526	36.02	1.50	5.34	5.32	+ .02	0
R	.623	.117	.526	60.20	2.50	5.32	5.32	00	0
R	.623	.117	.526	85.70	3.50	5.24	5.32	— .08	—2

When the distance between centers is 2 diameters or less it is found that the results obtained are much less accurate, being usually too large by about 4 per cent., as shown in Table v.

TABLE V.

S	λ	a_1	a	b	f	a	a_1	e	o
						//	//	//	
C	.560	.184	.396	42.8	1.50	3.99	3.89	+0.10	+3
C	.560	.184	.372	14.8	.50	3.81	3.66	+ .15	+4
C	.560	.184	.363	16.9	.50	3.40	3.50	— .14	—4
C	.560	.184	.332	16.6	.50	3.41	3.22	+ .19	+6
C	.560	.184	.297	19.6	.50	2.90	2.88	+ .02	+1
C	.560	.184	.266	21.3	.50	2.71	2.60	+ .11	+4
C	.560	.184	.266	20.4	.50	2.83	2.62	+ .21	+8
C	.560	.184	.251	23.3	.50	2.48	2.47	+ .01	0
C	.560	.184	.251	22.8	.50	2.51	2.47	+ .04	+2
C	.560	.184	.227	24.9	.50	2.32	2.23	+ .09	+4
C	.560	.184	.219	25.6	.50	2.22	2.13	+ .09	+4
S	.550	.060	.107	56.2	.50	1.01	1.06	— .05	—5
S	.550	.060	.107	56.8	.50	1.02	1.04	— .02	—2
C	.560	.060	.107	54.0	.50	1.07	1.08	— .01	—1
C	.560	.060	.107	53.2	.50	1.09	1.05	+ .04	+4
C	.560	.060	.107	53.5	.50	1.08	1.05	+ .03	+3
R	.623	.060	.107	57.2	.50	1.13	1.05	+ .08	+8
R	.623	.060	.107	58.7	.50	1.10	1.05	+ .05	+5
C	.560	.060	.075	70.8	.50	.79	.74	+ .05	+7
C	.560	.060	.075	72.0	.50	.77	.74	+ .03	+4

The measurement of the angular magnitude of sources of light too small to be resolved by the telescope may also be effected with a considerable degree of accuracy by providing the telescope objective with a slit or diaphragm which can be varied in size or width and measuring the distance between the centers of the diffraction fringes by means of a micrometer eyepiece.

In case the slit is used (as found most convenient in practice) the expression for the intensity of illumination at a distance γ from the center of the central bright band will be

$$I=\int f(\varphi)\frac{\sin^2\frac{\pi}{\alpha_0}(\gamma-\varphi)}{\left[\frac{\pi}{\alpha_0}(\gamma-\varphi)\right]^2}d\varphi. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

in which $f(\varphi)=y$ is the ordinate of an element of the source of light (supposed uniform) at a distance φ from the axis. If the source has a width α the limits of integration are evidently $\frac{\alpha}{2}$ and $-\frac{\alpha}{2}$.

First. In case the source is a uniformly illuminated slit $f(\varphi)$=const. and the expression for I becomes

$$I=c\int_{-\frac{a}{2}}^{+\frac{a}{2}}\frac{\sin^2\frac{\pi}{\alpha_0}(\gamma-\varphi)}{\left[\frac{\pi}{\alpha_0}(\gamma-\varphi)\right]^2}d\varphi.$$

or substituting $\frac{\pi}{\alpha_0}\gamma-\varphi=x$.

$$I=c_1\int_{\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)}^{\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)}\frac{\sin^2 x}{x^2}dx. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

This integral can not be found directly, but we may obtain the values of γ for which I is a maximum or minimum by differentiating (19) with respect to γ. This gives

$$\frac{dI}{d\gamma}=\text{const}\left[\frac{\sin^2\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)}{\left[\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)\right]^2}-\frac{\sin^2\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)}{\left[\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)\right]^2}\right]=0.$$

Hence

$$\frac{\sin\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)}{\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)}=\pm\frac{\sin\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)}{\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)} \quad \ldots\ldots\ldots\ldots \quad (20)$$

Writing this in the form

$$\frac{\sin\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)}{\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)}=\pm\frac{\sin\left[\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)-\pi\frac{\alpha}{\alpha_0}\right]}{\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)} \quad \ldots\ldots\ldots \quad (21)$$

we see that when $\frac{\alpha}{\alpha_0}<1$ the two sides of the equation have opposite signs, because

$$\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)<\pi<\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)$$

and we have

$$\frac{\sin\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)}{\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)}=-\frac{\sin\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)}{\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)} \quad \ldots\ldots\ldots\ldots \quad (21)$$

Expanding and solving for γ, we find

$$\gamma\,\text{tang}\,\frac{\pi\gamma}{\alpha_0}=\frac{\alpha}{2}\,\text{tang}\,\frac{\pi\alpha}{2\alpha_0} \quad \ldots\ldots\ldots\ldots\ldots \quad (22)$$

which gives the condition for a minimum when $0<\alpha<1$, or also when

$$2<\frac{\alpha}{\alpha_0}<3 \qquad 2m<\frac{\alpha}{\alpha_0}<2m+1.$$

When $1<\frac{\alpha}{\alpha_0}<2$ the sign of the two sides is the same, and we have

$$\frac{\sin\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)}{\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)}=\frac{\sin\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)}{\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)}$$

and, solving for γ as before,

$$\text{tang}\,\frac{\pi\gamma}{\alpha_0}=\text{tang}\,\frac{\pi\alpha}{2\alpha_0} \quad \ldots\ldots\ldots\ldots\ldots \quad (23)$$

$$\frac{\gamma}{\frac{\alpha}{2}}$$

which gives the conditions for a minimum, when

$$1<\frac{\alpha}{\alpha_0}<2 \qquad 3<\frac{\alpha}{\alpha_0}<4 \qquad 2m-1<\frac{\alpha}{\alpha_0}<2m$$

Finally, when

$$\frac{\alpha}{\alpha_0}=1, 3, 5 \ldots 2m-1, \text{tang}\frac{\pi\alpha}{2\alpha_0}=\pm\infty, \qquad \text{tang}\frac{\pi\gamma}{\alpha_0}=\pm\infty, \text{ and } \frac{\gamma}{\alpha_0}=\frac{3}{2}, \frac{5}{2}\ldots\frac{2m-1}{2}$$

When $\frac{\alpha}{\alpha_0}=2, 4 \ldots 2m$, $\text{tang}\frac{\pi\alpha}{2\alpha_0}=0$ $\text{tang}\frac{\pi\gamma}{\alpha_0}=0$, and $\frac{\gamma}{\alpha_0}=1, 2, 3, 4, \ldots . m.$

The curve obtained is shown in Fig. 9.

When the opening observed is circular the expression for the intensity becomes

$$I=\int_{-\frac{\alpha}{2}}^{+\frac{\alpha}{2}}\sqrt{\left(\frac{\alpha}{2}\right)^2-\varphi^2}\;\frac{\sin^2\frac{\pi}{\alpha_0}(\gamma-\varphi)}{\left[\frac{\pi}{\alpha_0}(\gamma-\varphi)\right]}\,d\varphi. \quad \ldots\ldots\ldots \quad (24)$$

Differentiating with respect to γ

$$\frac{dI}{d\gamma}=c\int_{-\frac{\alpha}{2}}^{+\frac{\alpha}{2}}\sqrt{\left(\frac{\alpha}{2}\right)^2-\varphi^2}\;\frac{\sin^2\frac{\pi}{\alpha_0}(\gamma-\varphi)}{\left[\frac{\pi}{\alpha_0}(\gamma-\varphi)\right]^2}\left(\cot\frac{\pi}{\alpha_0}(\gamma-\varphi)-\frac{1}{\frac{\pi}{\alpha_0}(\gamma-\varphi)}\right)d\varphi.$$

Substituting $x=\frac{\pi}{\alpha_0}(\gamma-\varphi)$ we have finally

$$\frac{dI}{d\gamma}=\int_{\frac{\pi}{\alpha_0}\left(\gamma-\frac{\alpha}{2}\right)}^{\frac{\pi}{\alpha_0}\left(\gamma+\frac{\alpha}{2}\right)}\sqrt{\left(\frac{\pi\alpha}{2\alpha_0}\right)^2-\left(\frac{\pi}{\alpha_0}\gamma-\varphi\right)}\;\frac{\sin^2x}{x^2}\left(\cot x-\frac{1}{x}\right)dx=0. \quad \ldots\ldots \quad (25)$$

Integrating this for different values of $\frac{\alpha}{\alpha_0}$ and $\frac{\gamma}{\alpha_0}$ we obtain the curve shown in Fig. 9, which can be expressed very closely indeed for $0<\frac{\alpha}{\alpha_0}<1$ by the simple formula:

$$\left(\frac{\gamma}{\alpha_0}\right)_c=\frac{1}{\pi}\left[\pi+2\left(\frac{\gamma}{\alpha_0}\right)_s-2\right] \quad \ldots\ldots\ldots\ldots \quad (26)$$

where $\left(\frac{\gamma}{\alpha_0}\right)_c$ is the ordinate to the dotted curve; $\left(\frac{\gamma}{\alpha_0}\right)_s$ is the ordinate to the full curve for any given value of $\frac{\alpha}{\alpha_0}$.

The results of some observations by this method on the size of a slit and of circular openings of varying diameters gave, in the case of a slit, errors varying from 1 to 15 per cent, the average error being about 8 per cent; and in the case of circular openings errors of from 3 to 25 per cent, the average error being about 12 per cent; a single setting only in most cases being taken. The accuracy of both this and the preceding method would undoubtedly be increased by taking the mean of a number of observations.

Of the two methods the first is by far the most accurate, but even the second gives results which are from eight to ten times as accurate as those which can be obtained by using the telescope directly.

The apparatus by which the observations in the preceding tables were made is shown in Fig. 1, Pl. II.

The objective of the telescope (a very fine four-inch glass, for the use of which I am indebted to the Worcester Polytechnic Institute) was fitted with a pair of adjustable slits whose distance apart could be regulated by a right and left hand screw geared to a rod (as shown in the plate) so as to be controlled by the observer, and the distance between the slits was read off by a small telescope beside the eyepiece of the large one. This simple and effective device has but one disadvantage. When the angle to be measured is so small as to be just beyond the power of the telescope it is necessary, in order to observe the first disappearance of the fringes, that the slits should be separated to the full width of the aperture. Under these circumstances the two pencils meet at a very large angle, usually several degrees, and the corresponding distance between the interference fringes is but a few thousandths of a millimeter, and in order to be visible as such must be highly magnified and accordingly very faint.

This difficulty may be entirely overcome by using, instead of the telescope, one of the forms of refractometer shown in Figs. 10 and 11.

The first of these will be recognized as one of the forms already described.*

The apparatus being adjusted so that interference fringes are visible, the telescope (a comparatively small one) is adjusted until the two images of its cross hairs in the mirror *m* coincide with the cross hairs themselves.

When this is the case it is clear that when the whole apparatus is pointed at a star (the mirror *m* being now removed) the two pencils will meet in the focus in the same phase and the breadth of the interference bands may be regulated by slight alterations of the pieces of the refractometer *without in any way affecting the intensity of the light.* But beside this incidental advantage is the much more important one that it is possible, by simply increasing the distance between the mirrors *a b*, to enormously increase the effective aperture of the telescope.

Fig. 2, Pl. II, shows, on a scale of one-fourth actual size, a plan of a proposed instrument for effecting this object. The optical arrangement adopted is that shown in Fig. 11.

This form, notwithstanding the greater number of glasses, has some decided advantages over that of Fig. 10. In addition to greater facility in adjustment and ease of construction it has the important advantage of preserving constant the width of the fringes notwithstanding the angular displacement of the whole apparatus.†

The instrument figured in Pl. II would be used as follows: The mirrors *a* and *b* being moved as close together as possible and the auxiliary mirror *m* being in place the mirror *a* is adjusted by the screws s, s, till the two images of a source of light L as viewed in the telescope T appear to coincide. Next, the mirror *m* is adjusted in azimuth by the screw K till the paths of the two pencils are equal. (As before mentioned this angular motion does not affect the mutual inclination of the pencils and therefore the breadth of the fringes is unaltered.) The telescope T is then adjusted till the two images of its illuminated cross hairs coincide with the cross hairs themselves and is then clamped. The mirror *m* is now detached and the instrument is ready for use.

Suppose the object to be measured is a minor planet or satellite. The whole instrument, which would have to be placed on an equatorial mounting, is pointed so that the image of the body is exactly on the cross hairs.

The interference fringes will at once appear if the adjustment has been properly made.

Next, by means of a right and left hand screw the mirrors *a* and *b* are separated *until the fringes disappear.* If this disappearance is due to an accident it will immediately become evident by observing any star in the neighborhood. If the examination of the star shows the fringes, while

---

* "Measurement by Light Waves," by A. A. Michelson, American Journal of Science. Vol. XXXIX, February, 1890.

† The same advantage obtains in the use of the instrument as a refractometer for measuring extremely small variations of the angular position of the mirror or mirrors *m*.

they are absent in the case of the planet, it may be considered certain that the cause of the disappearance in the latter case is its appreciable disk.

The angular diameter of the latter can be found (on the supposition of uniform illumination) by the formula

$$\alpha = 1.22 \frac{\lambda}{b}$$

where λ is the wave length of the light and b the distance between the centers of the mirrors a and b.*

From what has gone before it will be inferred that the chief object of the methods proposed is the measurement of the apparent size of minute telescopic objects such as planetoids, satellites, and possibly star disks, and also double stars too close to be resolved in the most powerful telescope. But it is clear that interference methods may also be employed for the measurement of star places. Thus in observations for right ascension the slits would be placed parallel to the meridian and the instant of passage of the central white fringe across the spider lines noted, and in observations for declinations the slits would be horizontal, the cross hair being brought to coincide with the center of the white fringe.

The increase in accuracy to be expected from this method would, however, be limited by the imperfections of our present means of measuring time and angles; still it would appear that by its use a one-inch glass may be used to do the work now required of a ten-inch.

CONCLUSION.

(1) Interference phenomena produced under appropriate conditions from light emanating from a source of finite magnitude become indistinct as the size increases, finally vanishing when the angle subtended by the source is equal to the smallest angle which an equivalent telescope can resolve, multiplied by a constant factor depending on the shape and distribution of light in the source and on the order of the disappearance.

(2) The vanishing of the fringes can ordinarily be determined with such accuracy that single readings give results from fifty to one hundred times as accurate as can be obtained with a telescope of equal aperture.

(3) The principal applications of the method herein described are the measurement of the apparent magnitude of very small or very distant sources of light, such as planetoids and satellites (though larger bodies are not excluded), and of the angular distances between very close double stars.

(4) On account of the narrowness of the interference fringes when a very minute body is under examination, the method of obtaining these fringes (by a pair of adjustable slits in front of the objective of a telescope) is open to objection from which the refractometer method is entirely free. Further, this last modification makes it possible to extend the effective aperture of the equivalent telescope without limit.

Thus while it would be manifestly impracticable to construct objectives much larger than those at present in use, there is nothing to prevent increasing the distance between the two mirrors of the refractometer to even ten times this size.

If among the nearer fixed stars there is any as large as our sun it would subtend an angle of about one-hundredth of a second of arc, and the corresponding distance required to observe this small angle is ten meters, a distance which, while utterly out of question as regards the diameter of a telescope objective, is still perfectly feasible with a refractometer.

There is, however, no inherent improbability of stars presenting a much larger angle than this and the possibility of gaining some positive knowledge of the real size of these distant luminaries would more than repay the time, care, and patience which it would be necessary to bestow on such a work.

In concluding I wish to take this opportunity of expressing my appreciation of the disinterested manner in which my efforts have been so ably and zealously seconded by Mr. F. L. O. Wadsworth, Fellow of Clark University.

---

* Better the distance between the centers of the apertures in front of these mirrors.

END OF VOL. V.

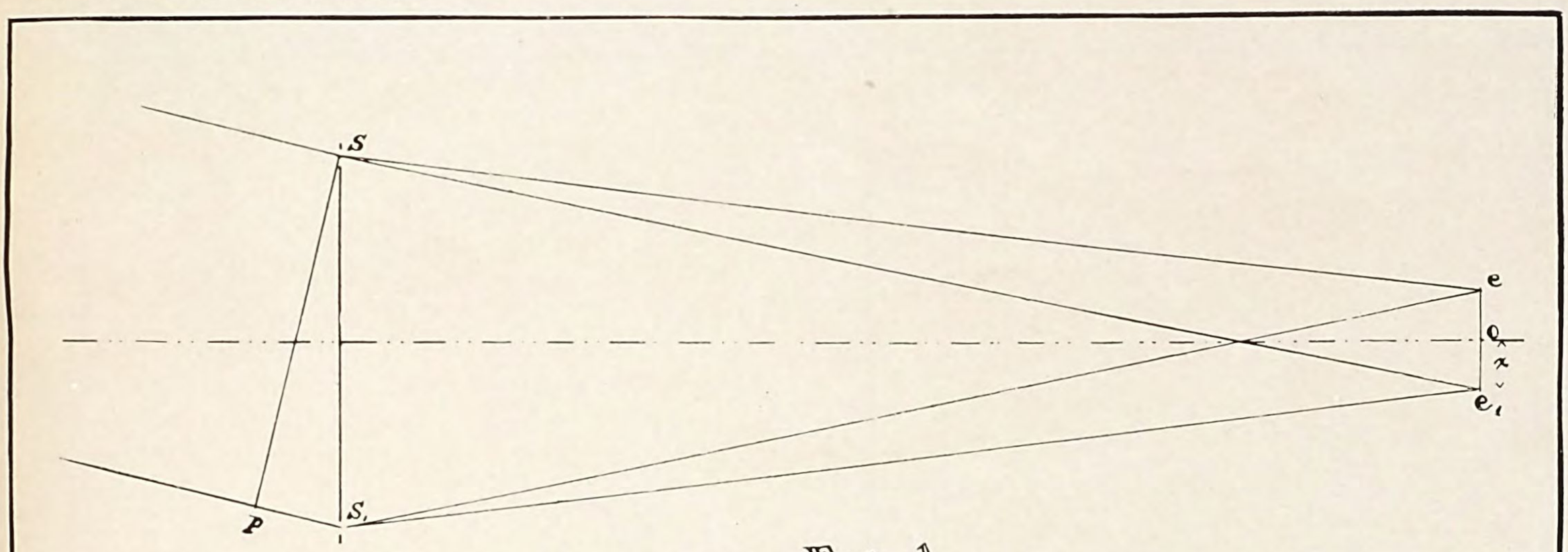


Fig 1

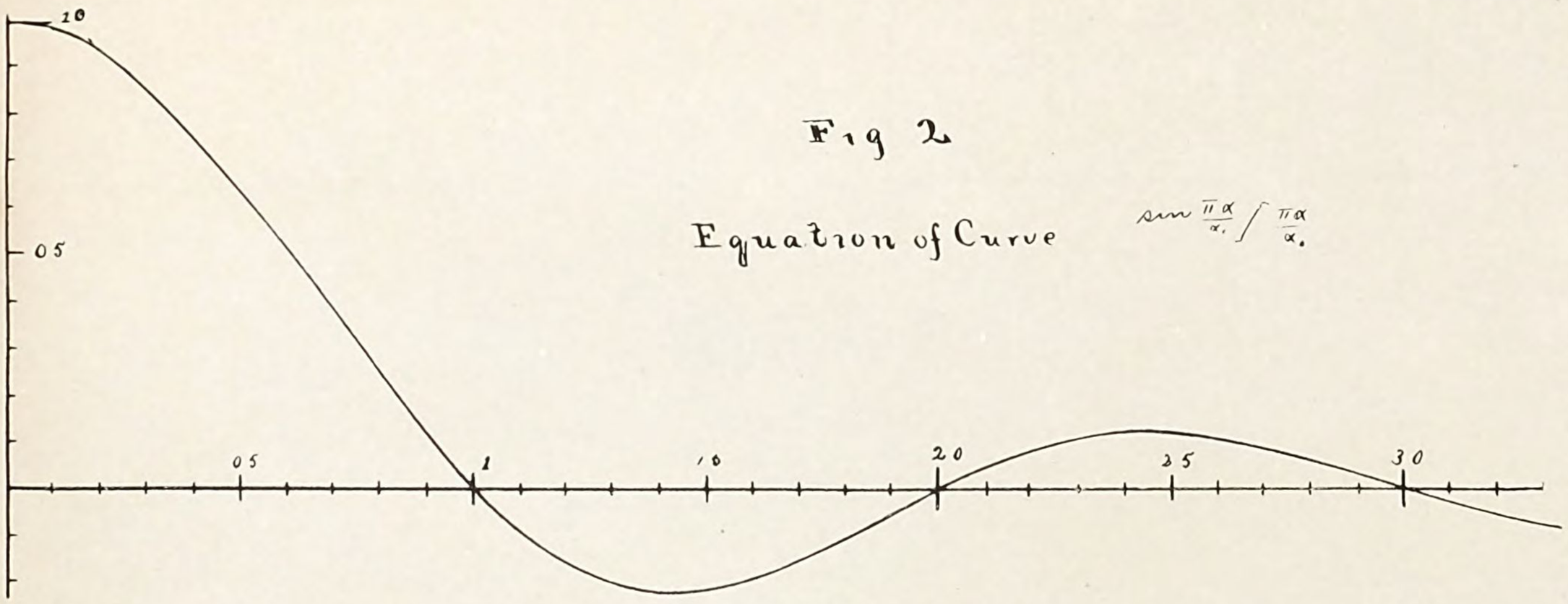


Fig 2

Equation of Curve $\sin \frac{\pi \alpha}{\alpha_1} \Big/ \frac{\pi \alpha}{\alpha_1}$

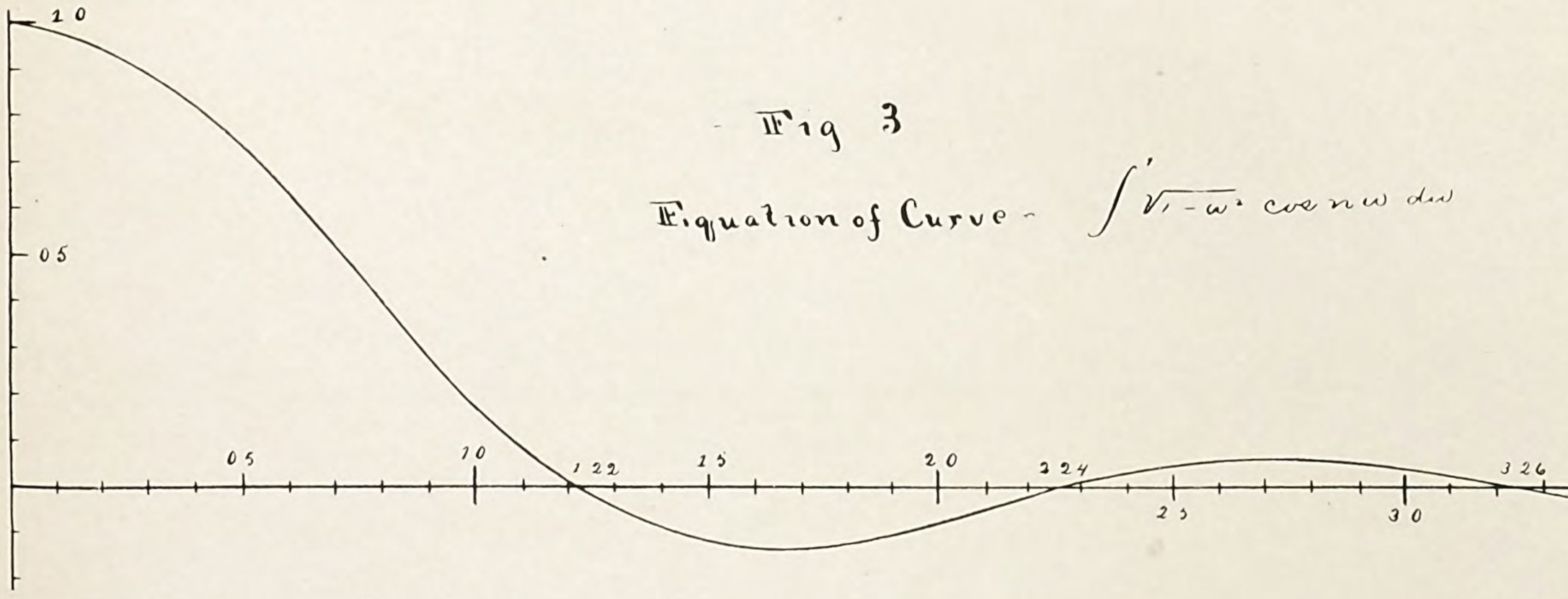
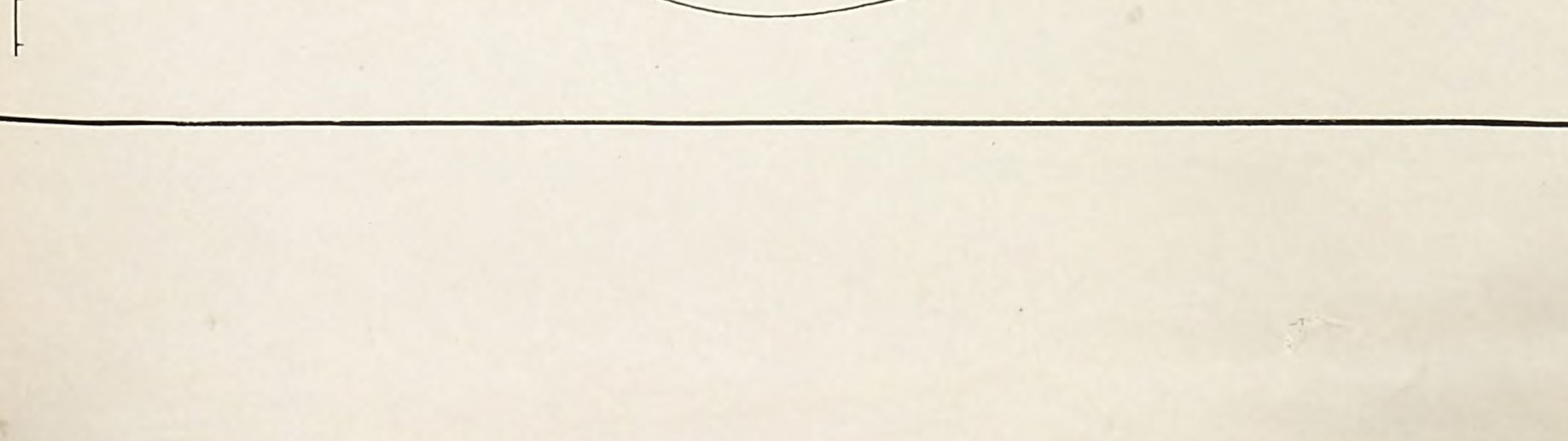
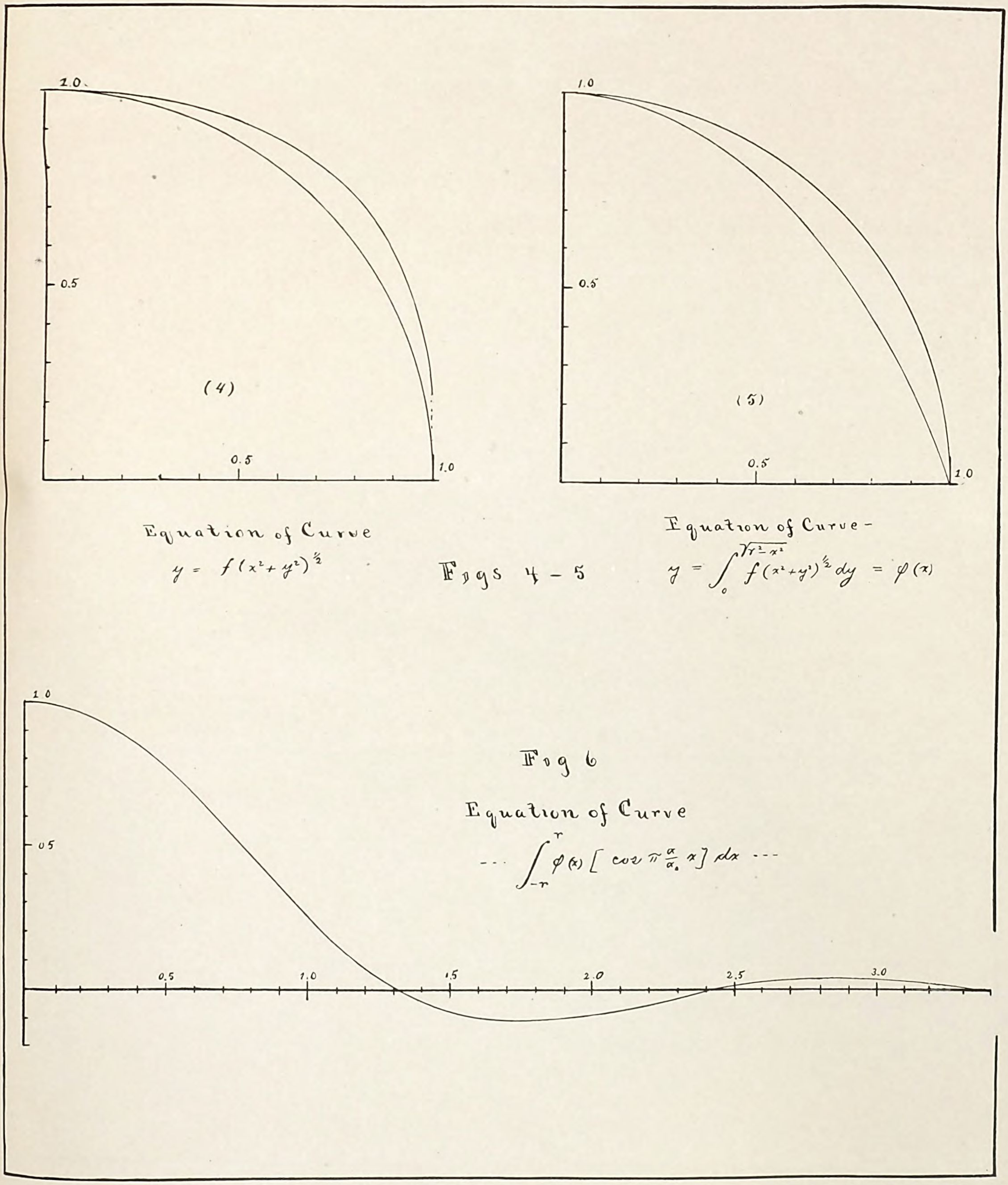


Fig 3

Equation of Curve - $\int \sqrt{1-w^2}\, \cos n w\, dw$





Equation of Curve

$$y = f(x^2+y^2)^{1/2}$$

Figs 4 - 5

Equation of Curve -

$$y = \int_0^{\sqrt{r^2-x^2}} f(x^2+y^2)^{1/2}\,dy = \varphi(x)$$

Fig 6

Equation of Curve

$$\cdots \int_{-r}^{r} \varphi(x)\left[\cos \pi \frac{\alpha}{\alpha_0} x\right] dx \cdots$$

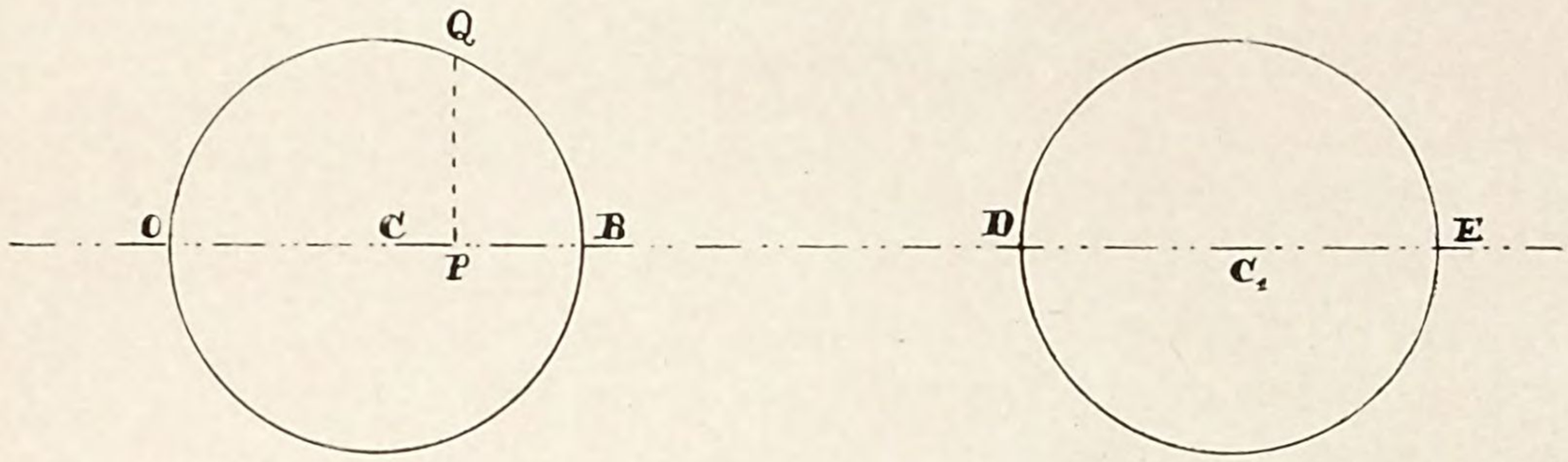


Fig 7

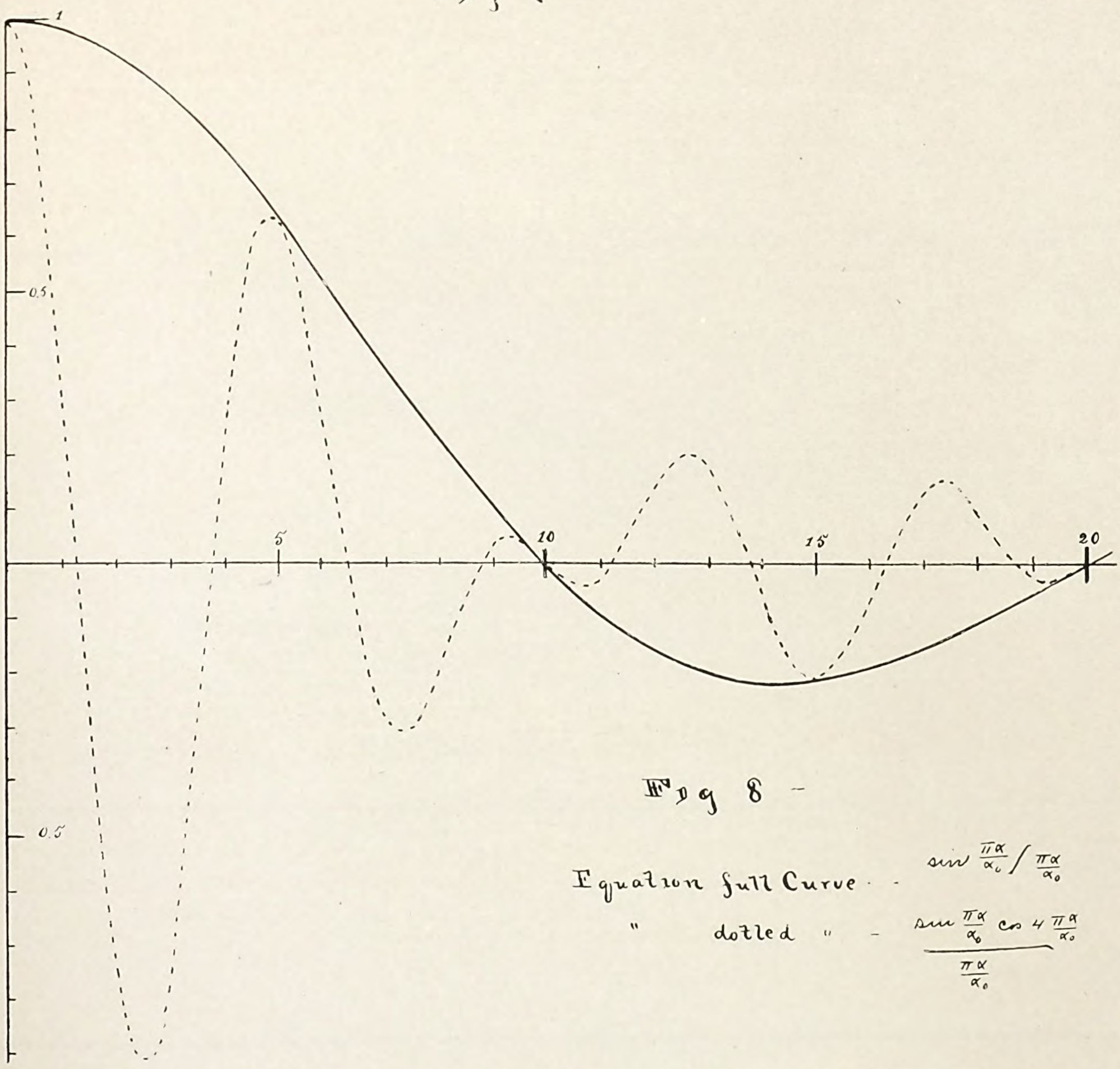
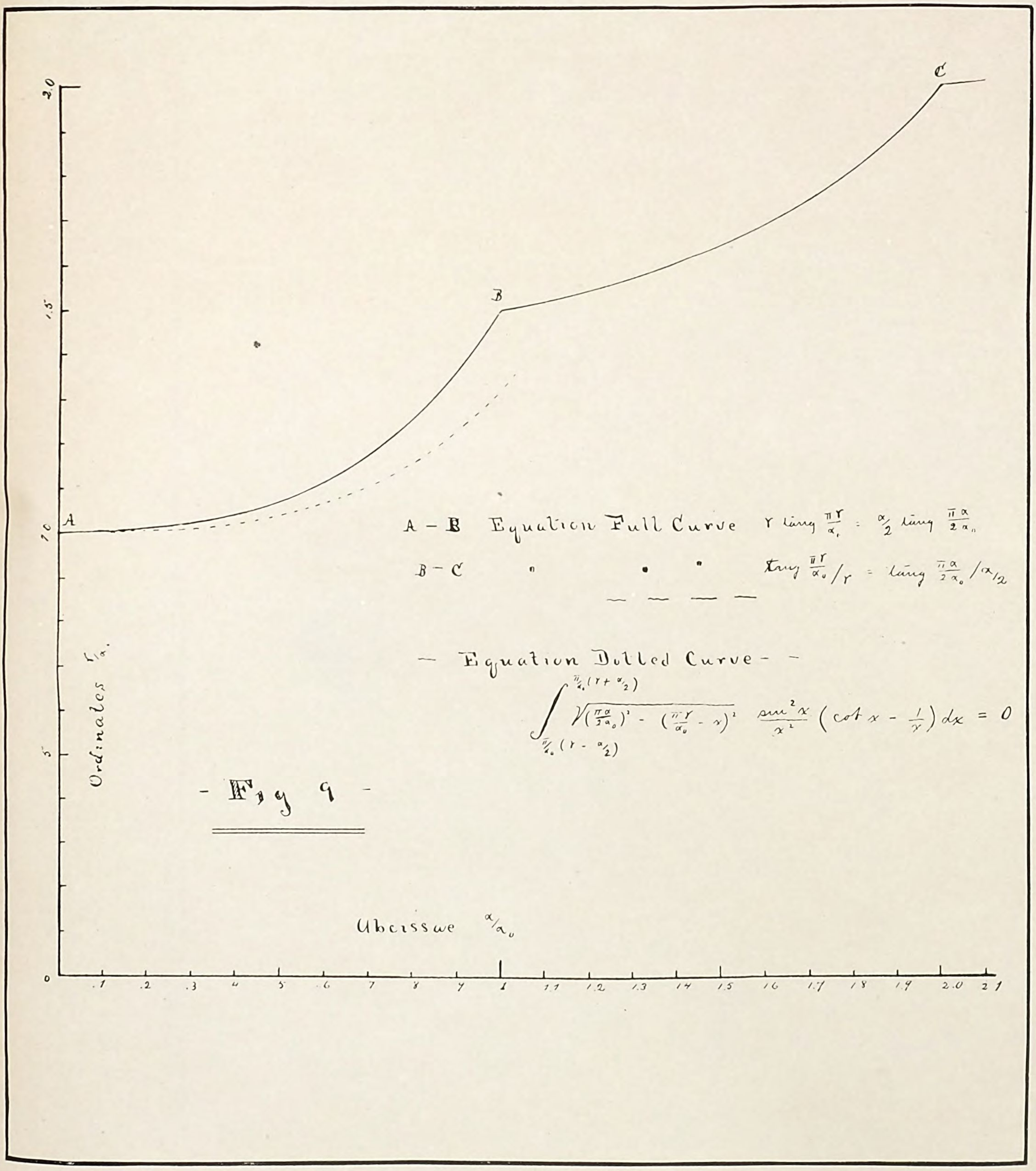


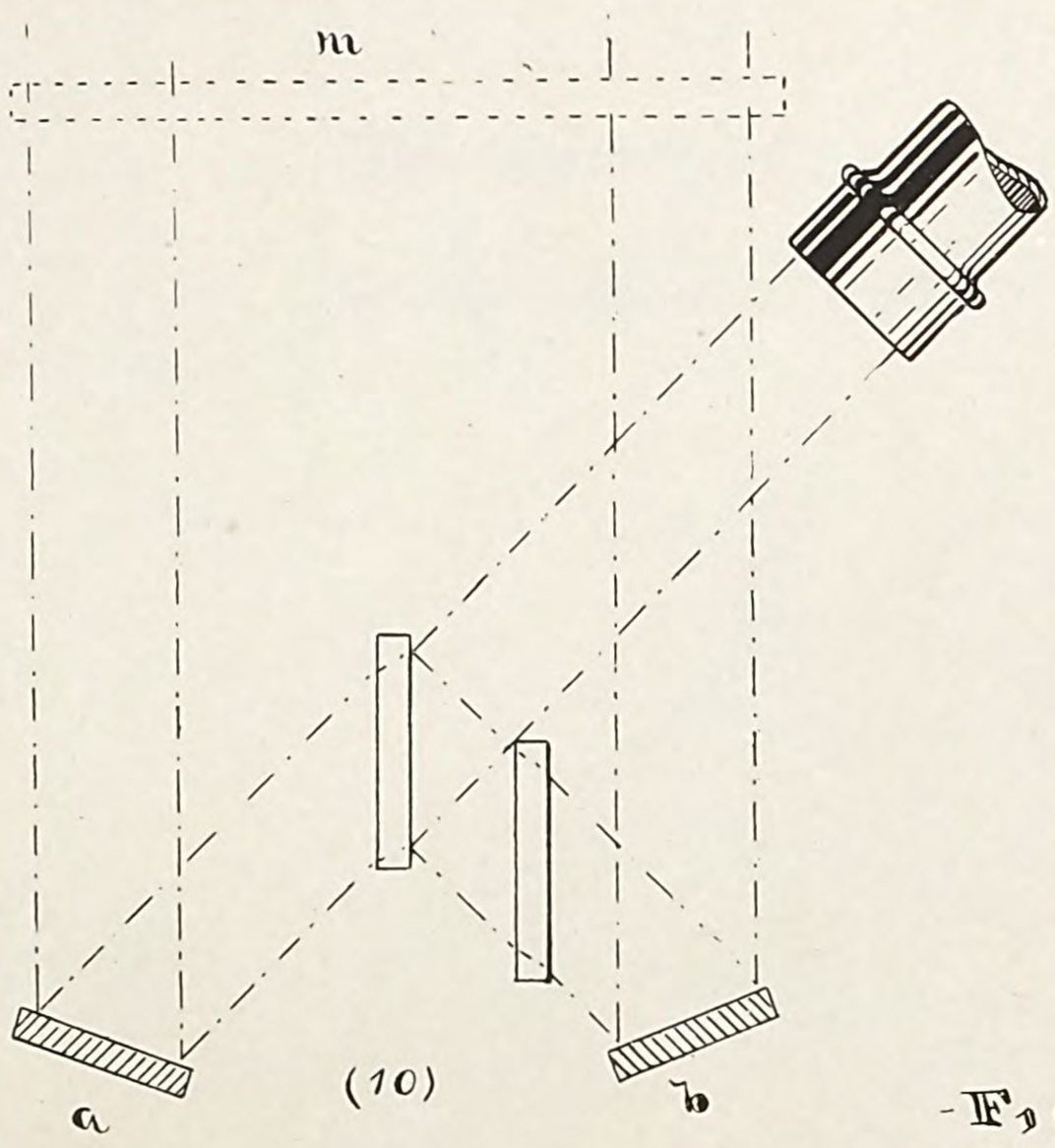
Fig 8 –

Equation full Curve - $\sin \frac{\pi\alpha}{\alpha_0} \Big/ \frac{\pi\alpha}{\alpha_0}$

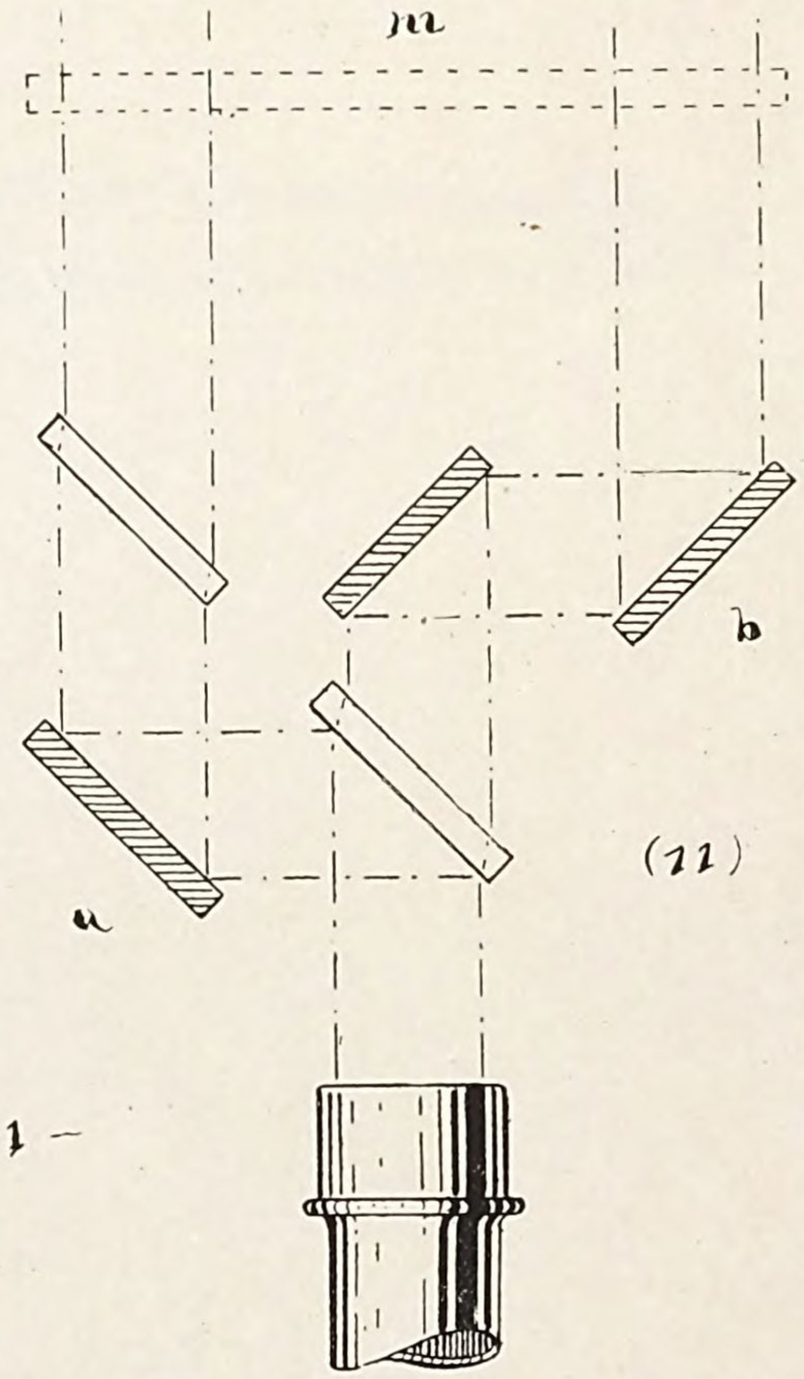
" dotted " - $\dfrac{\sin \frac{\pi\alpha}{\alpha_0} \cos 4\frac{\pi\alpha}{\alpha_0}}{\frac{\pi\alpha}{\alpha_0}}$


2.0
1.5
1.0
.5
0
A
B
C
Ordinales $r_{/\alpha_0}$
Ubcisswe α/α_0
.1 .2 .3 .4 .5 .6 .7 .8 .9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1
A – B Equation Full Curve $r \operatorname{tang} \frac{\pi r}{\alpha_1} = \frac{\alpha}{2} \operatorname{tang} \frac{\pi \alpha}{2 \alpha_0}$
B – C " " " $\operatorname{tang} \frac{\pi r}{\alpha_0} / r = \operatorname{tang} \frac{\pi \alpha}{2 \alpha_0} / \alpha/2$
— Equation Dotted Curve — —
$\int_{\frac{\pi}{\alpha_0}(r-\alpha/2)}^{\frac{\pi}{\alpha_0}(r+\alpha/2)} \sqrt{\left(\frac{\pi \alpha}{2 \alpha_0}\right)^2 - \left(\frac{\pi r}{\alpha_0} - x\right)^2} \; \frac{\sin^2 x}{x^2} \left(\cot x - \frac{1}{x}\right) dx = 0$

– Fig 9 –



(10)



(11)

Figs 10 11

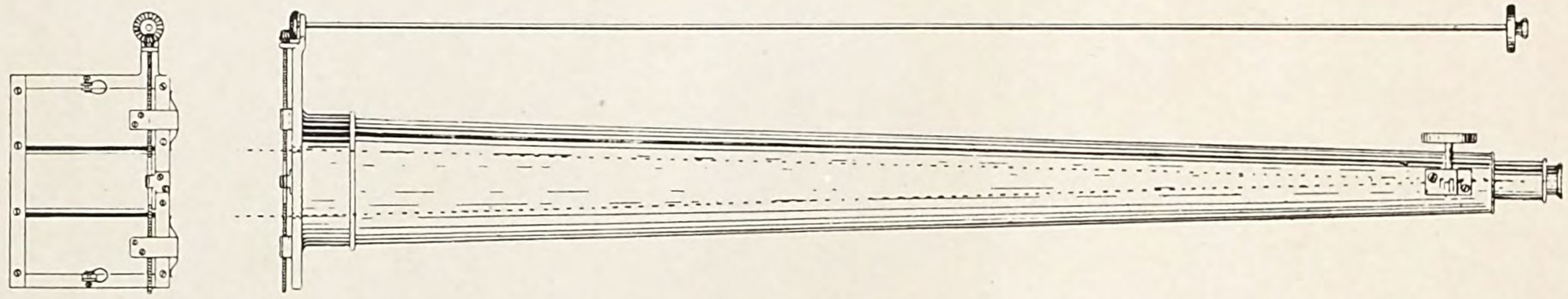


Fig. 1

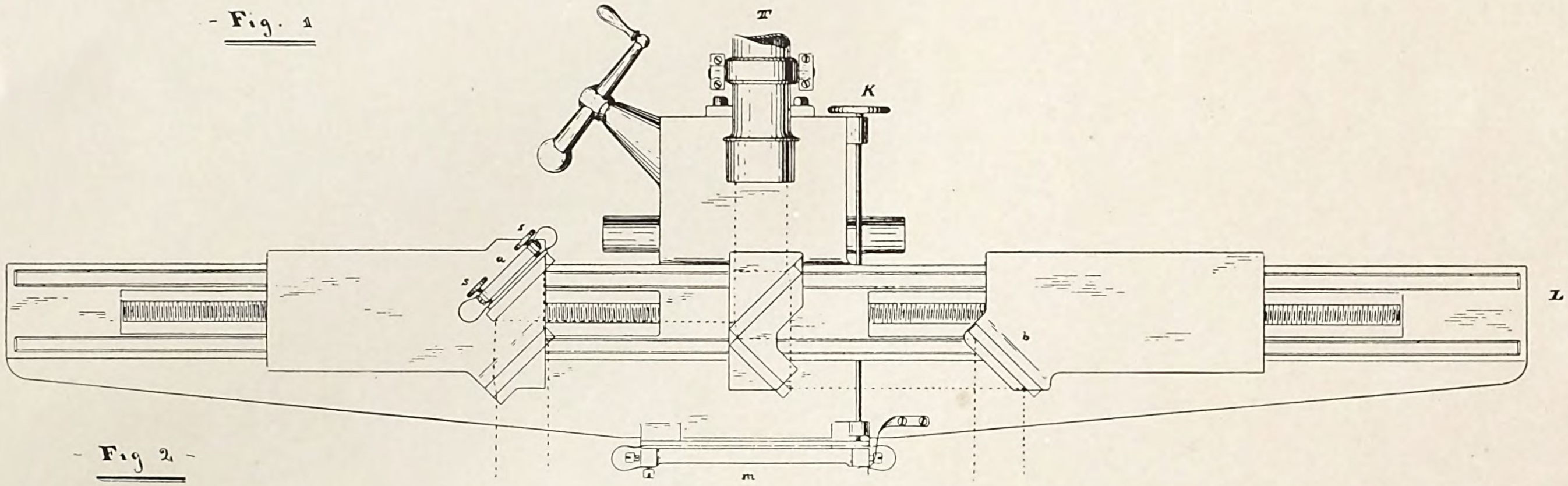


Fig 2

BSB Bayerische StaatsBibliothek
MDZ Münchener DigitalisierungsZentrum Digitale Bibliothek

Senate documents

Bd.: [418.] 1890/91, Vol. 6 = Congress 51, Sess. 2

Washington, DC 1894
Am.b. 3040-418,6
urn:nbn:de:bvb:12-bsb11548537-6